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WATER RESOURCES ACTIVITIES IN THE UNITED STATES. VIEWS AND COMMENTS OF THE STATES

Select Committee on National Water Resources,
U. S. Senate

December 1960

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86th Congress }
2d Session }

COMMITTEE PRINT NO. 6

WATER RESOURCES ACTIVITIES IN THE UNITED STATES

VIEWS AND COMMENTS OF THE STATES

SELECT COMMITTEE ON NATIONAL WATER RESOURCES
UNITED STATES SENATE

PURSUANT TO

S. Res. 48

EIGHTY-SIXTH CONGRESS

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DECEMBER 1960

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SELECT COMMITTEE ON NATIONAL WATER RESOURCES

(Pursuant to S. Res. 48, 86th Cong.)

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STATEMENT BY THE CHAIRMAN

JANUARY 14, 1960.

To the Members of the Select Committee on National Water Resources:

One of the first steps taken in assembling background information for the committee's studies of water resources activities under the authority of Senate Resolution 48, was to seek information on the experience and plans that each of the States had developed for dealing with emerging problems in the water resources field. To do this we addressed a letter to the Governor of each of the 50 States inviting him to furnish the committee with statements as to the present water problems of his State and those anticipated to arise between the present time and 1980. We also asked for the views of appropriate State officials as to what should be done toward solution of the problems.

The views and comments received range from brief letters commenting on the major problems facing a State to elaborate treatises covering all aspects of water resource development in the State, with projections of needs into the future. As our national water problems are essentially a composite of the many local and State problems, the responses received from the States make up a valuable compendium of information which makes a good background for looking at our national water resources problems. Taken as a group, the State comments may seem in themselves to reveal little other than the diversity of views and problems and diversity of State agencies selected by the Governors to provide information for the Committee. However, through all the comments run references and suggestions with respect to one or more of roughly a score of problem areas. The committee staff is preparing an analysis of the comments by subjects to provide a consolidated picture for use in connection with the deliberations of our committee.

In the meantime I am having the State comments printed as one of our series of committee prints, knowing that the State comments will be of great interest to you, to other Members of the Senate, to the States themselves, and to others interested in water resources development.

In addition to the comments of the States, a report on the water situation in Puerto Rico has been received from the Governor of Puerto Rico, and the Secretary of the Interior, in response to my request, has prepared a report for the committee on the water resources of the territories and island possessions of the United States. These are included with the State comments in this committee print.

ROB'T S. KERR,
Chairman, Select Committee on
National Water Resources.

COMMUNICATIONS

U.S. Senate,
Select Committee on National Water Resources,
June 23, 1959.

Hon. John Patterson,
Governor of Alabama,
Montgomery, Ala.

My Dear Governor Patterson: Under the provisions of Senate Resolution 48, adopted April 20, 1959, the Senate Select Committee on National Water Resources has been established. The committee is taking steps now to assemble and analyze as expeditiously as possible information on the Nation's water problems.

The committee is obtaining basic data on the Nation's water supply and information on proposed Federal plans and programs from agencies of the executive branch of the Federal Government. The committee also considers it important to obtain information on the experience and plans that each of the States may have developed. Accordingly, we should appreciate it very much if you would furnish the committee with a statement as to the water problems of your State, both present and anticipated to arise between now and 1980. We also should welcome a statement of your views, or the views of the appropriate officials of your State, as to what should be done toward the solution of these problems.

A copy of a general outline of proposed procedures for the staff work of the committee is enclosed for your information, together with a copy of Senate Resolution 48. Your comments on any subject in the outline which you consider to be related to the needs of your State will be most helpful, together with your views on any of the matters mentioned in Senate Resolution 48 or any specific problems which you foresee for water resources use in your State or region from the present time to 1980.

In view of the workload and time limits imposed upon the committee, it would be most helpful if your material would be furnished in the form of a summary statement of not more than 10 pages, accompanied by such supporting data as you believe desirable. We would appreciate it if the material could be made available not later than October 1, 1959.

Your courtesy in furnishing this information will be greatly appreciated.

Sincerely yours,

Rob't S. Kerr, *Chairman.*

(Identical letter sent to each Governor.)

General Outline of Proposed Procedures

First phase: Development of technical background for committee report:
- I. Statement of the existing situation and present trends, by regions:
  - A. Summary of water resources available.
  - B. Statement on withdrawal and use of water.
  - C. Fundamental problems.
  - D. Ground water problems.
  - E. Water use for pollution abatement.

II. Projections of future demands for water and water related activities considering relationships of availability and costs (supply-demand relationships):
A. Population projections.
B. Municipal water use.
C. Agricultural use of water.
D. Water needs of industries (including atomic).
E. Electric energy.
F. Navigation.
G. Flood control.
H. Water recreation.
I. Fish and wildlife.
J. Trends in use of water for waste disposal.
K. Alaska and Hawaii.

III. Means of meeting future demands (new techniques):
A. Conventional methods of adding new supplies and costs thereof.
B. Vegetational management (reduction of evapo-transpiration).
C. Weather modification (induce precipitation).
D. Evaporation reduction and seepage control.
E. Desalinization.
F. New techniques in multiple-purpose river management.
G. Effects of nuclear energy.
H. New technical methods of improving water supply methods (improved ground water use, water recovery, etc.).

Second phase: Staff analysis of technical, economic, and other factors influencing the national interest in water development:
I. General:
A. General analyses of material obtained in phase I.
B. Analyses of sample regions and basins.
II. Who should do what:
A. Expected Federal development under existing law.
B. Expected non-Federal development.
C. Ways in which Federal agencies and others can help in meeting water needs.

Third phase: Preparation of report.

[S. Res. 48, 86th Cong., 1st sess.]

RESOLUTION

Whereas adequate supplies of water of acceptable quality are essential to the continued welfare of the Nation, to its agricultural and industrial development, and to the national security; and

Whereas authoritative estimates forecast that by 1980 the United States population will increase to two hundred and fifty million and that the use of water will have increased by more than 50 per centum; and

Whereas in many sections of the United States such additional supplies of water of suitable quality are available, if at all, only at costs that would impede or prevent the increasing uses needed by the expanding population, agriculture, and industry; and

Whereas adequate provision for wildlife and recreational values, as well as provision of adequate quantity and quality of water supplies, and the economic utilization of hydroelectric and navigation potentials, stream sanitation, and other water resource benefits requires coordination of all such prospective uses and developments by public and private agencies; and

Whereas there are many new technical methods that may increase the usable water supplies by means of weather modification, evaporation reduction, desalination, seepage control, waste-water salvage, application of nuclear energy, and similar improvements; and

Whereas the Senate, in connection with provision for needed development and coordination of water resources, desires to have recommendations relative to the needed programs, their character and timing in relation to population and economic use requirements and associated benefits such as wildlife and recreation: Now, therefore, be it

Resolved, That there shall be established a select committee which shall make exhaustive studies of the extent to which water resources activities in the United States are related to the national interest, and the extent and character of water resource activities, both governmental and nongovernmental, that can be expected to be required to provide the quantity and quality of water for use by the population, agriculture, and industry between the present time and 1980, along with suitable provision for related recreational and fish and wildlife values, to the end that such studies and the recommendations based thereon may be available to the Senate in considering water resources policies for the future.

Sec. 2. (a) The committee shall be composed of three members of the Committee on Interior and Insular Affairs, three members of the Committee on Public Works, three members of the Committee on Interstate and Foreign Commerce, and three members of the Committee on Agriculture and Forestry; all said members to be designated by the chairman of the respective committees, at least one member designated from each of the above committees being selected from the minority membership thereof. The committee shall be designated "The Senate Select Committee on National Water Resources."

(b) Any vacancy in the membership of the committee shall not affect its powers, and any vacancy in the membership of the committee shall be filled in the same manner as provided for determining the original membership.

(c) Six members of the committee shall constitute a quorum.

(d) The chairman shall be chosen by the members at the first meeting.

Sec. 3. The committee shall, without limiting the scope of the study hereby authorized, direct its attention to the following matters:

(a) The character and extent of water resource projects that will be needed to be in operation between the present time and 1980 in order to supply the water use requirements of population, agriculture, and industry, including but not limited to navigation development and hydroelectric power generation, and with appropriate provision for flood control, and the realization of recreational and wildlife values.

(b) The character of legislation that may encourage the adoption of new technical methods and improved process for increasing the usefulness of available water resources, including but not limited to weather modification, evaporation and evapo-transpiration reduction, desalination of saline and brackish waters, seepage control, waste-water salvage, and the application of nuclear energy.

Sec. 4. The committee shall transmit to the Senate not later than January 31, 1961, the results of the study herein authorized together with such recommendations as may at that time be found desirable.

Sec. 5. In the conduct of this study full use shall be made of the experience, knowledge, and advice of private organizations, schools, institutions, and individuals. The committee may divide the work among such groups and institutions as it may deem appropriate and may enter into contracts for this purpose: *Provided, however*, That no such contract shall become effective until submitted to the members of the select committee and approved by a majority vote thereof. Full use shall be made of studies and plans prepared by executive agencies, and such agencies are requested to give the committee or any of its authorized study groups or consultants such assistance as may be required.

Sec. 6. (a) For the purpose of this resolution, the committee is authorized to employ on a temporary basis through January 31, 1960, such technical, clerical, or other assistants, experts, and consultants as it deems desirable. The expenses of the committee under this resolution, which shall not exceed $175,000, shall be paid from the contingent fund of the Senate upon vouchers approved by the chairman of the committee.

(b) For the purposes of this resolution, the committee, or any duly authorized subcommittee thereof, is authorized to hold such hearings, to sit and act at such places and times, to require, by subpena or otherwise, the attendance of such witnesses and the production of such books, papers, and documents, to administer such oaths, to take such testimony, to procure such printing and binding, and to make such expenditures, as it deems desirable. The committee shall cease to exist at the close of business on January 31, 1961.

November 16, 1959.

Hon. Fred A. Seaton,
The Secretary of the Interior, Department of the Interior, Washington, D.C.
(Attention: Mr. Lawrence Stevens, technical review staff).

My Dear Mr. Secretary: In order to round out the picture on water-supply problems of the United States, the Senate Select Committee on National Water Resources would like to have information and data on the water resources of the territories and island possessions of the United States. We already have an excellent statement on the water situation in Puerto Rico which was submitted to the committee by Governor Luis Muñoz Marín, and I am writing to ask the Interior Department to furnish us a report on the water resources and problems of the other insular and territorial possessions under your jurisdiction, which it is understood includes the Virgin Islands, Guam, American Samoa, and the Trust Territory of the Pacific Islands.

We would like to have a report of not more than 5 or 10 pages on each of the territories and island possessions, summarizing the water resources available, and giving information on present and projected future demands for withdrawal and use of water and water related activities, means of meeting future demands, and any additional information and suggestions you may have with respect to the water resources and problems in these areas. We would like to have the reports by the first of January, or earlier if possible. The committee staff will be glad to furnish any further information needed as to the requirements of the committee.

I appreciate very much the contribution which the Department of the Interior and its agencies are making to the work of this committee, and I look forward with great interest to receiving the reports which are nearing completion.

With all good wishes, I am,
Sincerely yours,

Rob't. S. Kerr, *Chairman.*

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STATE COMMENTS ON WATER RESOURCES AND PROBLEMS

ALABAMA

Department of Public Health,
Montgomery, Ala., September 17, 1959.

Hon. Robert S. Kerr,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: Your letter to Governor Patterson with respect to obtaining basic data on the Nation's water supply under the provisions of Senate Resolution 48, has been given a great deal of thought, particularly with respect to the State of Alabama.

For many years those interested in water resources in the State of Alabama have been concerned with the effect on these resources by an increasing urban population, industrial development of the State, agricultural irrigation, recreational uses, and waterway improvement for navigation and power development. The urgency of the need for factual information on water quality was recognized in 1947 when the Alabama State Legislature created the water improvement advisory commission for the purpose of investigating and reporting on the quality of the State's water resources. Until 1955, the quantity and use of the State water resources had not been given serious consideration. The drought period 1952–55, emphasized the need for an evaluation of water uses and resources for the present and future. Motivated by the effect of this drought, representatives of agencies and groups concerned with water resources submitted a report to the Governor of the State urging legislative action on a plan to study the State's water resources and to develop a water policy for the State.

It was not until 1959 that the State legislature passed legislation, subsequently approved by the Governor, creating a water resources study commission, for the purpose of studying the State's water resources and recommending to the legislature a basic water control policy best suited to the State's future water needs. Members of this commission have recently been appointed by the Governor. A copy of the act creating the water resources study commission (act No. 74, regular session, 1959) is attached.

While factual information cannot be assembled for submission to your committee until the Water Resources Study Commission has completed its study and report, I am attaching a copy of a report submitted to the Governor in 1955 which contains statements in support of the need for the development of a basic water resource policy.

As previously mentioned, the need of water quality was thoroughly investigated by the water improvement advisory commission during the period 1947–49. On the basis of the report of this investigation and recommendation of this commission, the 1949 State legislature empowered the commission with authority over water pollution. In 1953 the State legislature strengthened the commission's position with respect to its authority and changed the name of the agency to the water improvement commission. For your committee's information, I am attaching copies of the Alabama water pollution control law and reports indicating the status of water quality in Alabama.

Yours very truly,

D. G. Gill, M.D., *State Health Officer.*

Attachments:[1]

1. "Report of Progress, 1957–58," State of Alabama Water Improvement Commission, 32 pp.
2. "Studies of Pollution in Streams of Alabama," State Water Improvement Advisory Commission, 1949, 298 pp.

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[1] Not reprinted herein.

3. Alabama Pollution Control Act (No. 463, regular session 1953) approved August 31, 1953.

4. "Streams of Progress," Alabama Water Improvement Commission, pictorial report.

5. Alabama Water Resources Study Commission Act (No. 74, regular session, 1959). Approved June 18, 1959.

6. "Alabama's Water Resources, A Plan for the Creation of a Temporary Commission To Study the State's Water Resources and to Develop a Water Policy for the State," 32 pp.

ALASKA

STATE OF ALASKA,
OFFICE OF THE GOVERNOR,
Juneau, September 29, 1959.

Hon. ROBERT S. KERR,
Chairman, U.S. Senate Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: The enclosed summary statement is forwarded pursuant to your request of June 23 with reference to Senate Resolution 48, adopted April 20, 1959. I note that the statement includes no mention of the bill introduced by Senators Bartlett and Gruening earlier this year to create an independent commission to study water development needs in Alaska, with which proposal I am in hearty accord.

Sincerely yours,

WILLIAM A. EGAN, *Governor.*

Enclosure.

ALASKAN WATER RESOURCE PROBLEMS

Other than the old placer mining problem of maintaining a sufficiently large flow of water to wash the gold from the gravel, Alaska has had no serious problems until very recently. As a matter of fact, most Alaskans will be quick to agree that there is too much water in Alaska, both underfoot and precipitation. However, with the growth of population and the increased industrialization now starting, problems in connection with our water resources are beginning to be of serious concern and will become greater. How much greater depends on the rate of industrial expansion and the steps taken to meet the problem. The approaching problems can be considered under the following headings.

1. *Law.*—Several laws concerning water resources are now in effect, but a comprehensive code covering all aspects of the several problems should be prepared before the problems arise. Some very wise provisions were made in Alaska's Constitution concerning our water resources, and interpretation of these sections is greatly needed for the guidance of all concerned. Article VIII has three sections which are quoted as follows:

> SEC. 3. Wherever occurring in their natural state, fish, wildlife, and waters are reserved to the people for common use.
>
> SEC. 13. All surface and subsurface waters reserved to the people for common use, except mineral and medicinal waters, are subject to appropriation. Priority of appropriation shall give prior right. Except for public water supply, an appropriation of water shall be limited to stated purposes and subject to preferences among beneficial uses, concurrent or otherwise, as prescribed by law, and to the general preservation of fish and wildlife.
>
> SEC. 14. Free access to the navigable or public waters of the State, as defined by the legislature, shall not be denied any citizen of the United States or resident of the State, except that the legislature may by general law regulate and limit such access for other beneficial uses or public purposes.

Section 1311 of Title 43 of United States Code Annotated, regarding submerged lands within State boundaries, states in part:

> (d) Nothing in this chapter shall affect the use, development, improvement, or control by or under the constitutional authority of the United States of said lands and waters for the purposes of navigation or flood control or the production of power, or be construed as the release or relinquishment of any rights of the United States arising under the constitutional authority of Congress to regulate or improve navigation, or to provide for flood control, or the production of power;

Some of the questions which arise from the above, and which need to be answered are the following: What may be considered beneficial uses? How is public access to be obtained when a lake or a river is ringed or lined with private property? What are navigable waters? What is a lake as distinguished from a pond? What waters will be under the permanent jurisdiction of the State? What waters will be conveyed with surrounding uplands when transferred from State to private ownership?

2. *Assessment of resources.*—Projects and programs should be initiated to fully determine in the State of Alaska the location, quantity, and quality of all our water resources. The U.S. Geological Survey has been doing this to a limited extent for some years, but that work has not been nearly adequate, and we are informed that since we have achieved statehood this work on their part will be diminished. It is advisable that cooperative agreements with Federal agencies, such as the U.S. Geological Survey, be sought and entered into so that the State and its people can benefit to the greatest extent from participating funds and programs. The point to be made here is that for more proper and efficient planning for the best uses of our water resources, we must first know accurately the extent of our resources. The data collected should be made available to all interested persons, firms, or agencies.

3. *Pollution.*—Future water pollution is a threat to our great fishing industry, as well as to our recreation potentials. There will be an increasing number of industrial plants which will be dumping chemical and other wastes if not regulated. Increasing population will account for greater amounts of sewage, if the present trends continue. Chemicals and sewage are fatal to fish and wildlife. Mining will do its share of pollution by means of chemicals from treatment mills and sediments from placer operations unless properly regulated. All of these possible sources of pollution can be operated without harmful effects if the proper safeguards are taken. A water pollution board presently exists in the State of Alaska which takes care of the chemical aspects of pollution. A newly enacted fish and game code contains provisions for the prevention of pollution and/or otherwise damaging State waters for the protection of fish and game.

4. *Hydroelectric developments.*—It is well recognized that the establishment of hydroelectric plants will help pave the way for the industry that is so greatly needed in Alaska. Yet, hydroelectric developments will necessarily interfere with other uses of water resources and land uses. For example, the Copper River has produced some $3 million worth of salmon. If the proposed Woods Canyon Dam is built, it will unquestionably have a detrimental effect on the Copper River salmon. No method has yet been devised to eliminate salmon losses caused by high dams. Further, some of the proposed hydroelectric developments in Alaska will submerge large areas of lands which are prospectively valuable for agricultural uses and mineral resources. Therefore, all hydroelectric proposals should be very carefully studied and evaluated to determine which will be the most valuable line of action for the State of Alaska and its residents to follow.

5. *Recreation.*—Bodies of water are among our most important sources of recreational facilities. The State's residents need recreational outlets, and it is essential to have as much recreational area as possible for the benefit of the tourist industry, which is of great economic importance to the State of Alaska. If a proposed commercial use for a certain body of water is incompatible with the recreational use of that body of water, then someone must decide as to which use should have priority.

6. *Control of flow.*—To maintain a minimum flow of water for its various uses, criteria needs to be established and regulations created. If it appears that irrigation in an agricultural district is lowering the water table too far, well spacing and rates of flow from the wells should be established. A minimum allowable flow for each watershed to sustain fish and wildlife may become a problem in certain localities, and should be regulated.

For solution of the above problems and others that will occur, full time water use planning personnel should be engaged. This could be in the form of a water engineer and staff as in some States, or an official water-use planning board composed of representatives from the various State and Federal agencies concerned, which would be required to work out the water problems jointly. This office or board would bring together the various economic development needs, the human resource needs, natural resource needs, etc. After all known facts and information were accumulated, they would evaluate them and determine in each case which use would provide the greatest benefit to the State that is still consistent with supplying the human needs of the people. Policies would be established for future guidance. A code would be promulgated and adopted as mentioned earlier.

ARIZONA

Office of the Governor,
State House,
Phoenix, Ariz., October 7, 1959.

Hon. Robert S. Kerr,
Chairman, Senate Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

My Dear Mr. Chairman: Enclosed please find a statement that is submitted by the State of Arizona. This statement is supplemented by documents[1] enumerated as follows:

"Summary of Ground Water Law of Arizona and the Rules and Regulations of the State Land Department Concerning Ground Water, 1958": Arizona State Land Department.
Arizona Power Authority 14th Annual Report: Arizona Power Authority.
"Arizona Statistical Review, 1958": Valley National Bank.
Wildlife News, Annual Report, Winter, 1959: Arizona Game and Fish Department.
Institute of Atmospheric Physics (brochure): University of Arizona.
"Seeding of Summer Cumulus Clouds Scientific Report No. 10, Institute of Atmospheric Physics": University of Arizona Institute of Atmospheric Physics.
Annual Report on Ground Water in Arizona 1957–58: Arizona State Land Department and U.S. Geological Survey.
Annual Report (1957–58), State Land Commissioner: Arizona State Land Department.
"Underground Water Resources of Arizona 1953 Report by Underground Water Commission": Arizona Underground Water Commission.
Annual Report, Salt River Project, Inc., "The Phoenix Story, an Adventure in Reclamation": Salt River Valley Water Users' Association.
Annual Report, Watershed Management Division, State Land Department, 1958–59: Arizona State Land Department.
"Water Log of the Colorado River 1958": U.S. Bureau of Reclamation.
"Arizona Watershed Program Proceedings of Interagency Conference 1957": State land department, watershed management division.
"Arizona Watershed Program Proceedings of Interagency Conference 1958": State land department, watershed management division.
"Projection of Population Growth to 1980" (letter): H. A. Leggett, Valley National Bank.
Annual Report, Arizona Interstate Stream Commission, 1957–58: Arizona Interstate Stream Commission.

I appreciate this opportunity to present the State's position.

Sincerely,

Paul Fannin, *Governor of Arizona.*

Measured by standards for the Nation as a whole, Arizona is a water-deficient State. Its economy, insofar as it is dependent on water supply, has been and is contrived by skillful water management and engineering.

Population, industry, and agriculture are concentrated in the southern half of the State, where the climate is semitropical and arid. Most of the annual precipitation falls on the higher northern half of the State, from which most of the unevaporated portion drains through the lower southern half toward the Colorado River. Numerous dams and reservoirs on the major rivers within the State trap and store this water.

In addition to this surface water supply, water has been deposited in the alluvial fill valleys of the desert region through the centuries, and this underground supply has been extensively tapped by deep wells.

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[1] Not reprinted herein.

Total use of water in Arizona is estimated to be 6,600,000 acre-feet annually. Of this total amount, about 4,500,000 acre-feet are pumped from ground water storage, while surface water diversions account for about 2,100,000 acre-feet.

With this basic water resource Arizona annually produces irrigated crops and livestock worth in excess of $400 million, manufactured products worth approximately $500 million, and supports a population of 1,300,000.

While the use of water by agriculture amounts to approximately 6,300,000 acre-feet annually, water use by municipalities and industry is increasing about eight times faster than the rate of increase for crop irrigation.

Water laws and rights

Arizona water law is based on the right of prior appropriation and beneficial use. The right to use water obtained under this law is appurtenant to the land upon which it is first applied. The water right cannot be separated from the land by sale, rent, or lease, but it can, of course, be utilized for any beneficial purpose on the land to which it is appurtenant.

Unlike surface water, ground water is not subject to appropriation in Arizona. It may be applied on the land from which it is pumped subject only to the doctrine of reasonable use. Under the Arizona Ground Water Code of 1948, specific areas may be declared critical, under certain conditions, and the drilling of new wells for irrigation purposes restricted.

It is essential to the stability and growth of Arizona that the established water laws of the State prevail over any asserted superior authority of the Federal Government. We recommend enactment of legislation by Congress to protect States' water rights against the Federal Government.

Future needs

Arizona is the second fastest growing State in the Nation. Its rate of population gain in the period 1947–57 was 74 percent. In that same period, the value of manufactured products in the State increased from $117 million annually to approximately $460 million, and the value of crops and livestock rose from $180 million to $421 million, according to the University of Arizona.

Establishment of new industries and expansion of old ones creates more jobs for the steady influx of people to the State. Conservative projections of growth indicate a State population of 2,750,000 to 3 million by 1980.

To meet the water requirements for this added population, about 500,000 acre-feet of additional water will be needed.

If the area pattern of growth remains unchanged most of the population increase will be concentrated in the southern half of the State in which about 88 percent of Arizona's people now live. The pressure upon limited water supply will continue and increase the competition between urban and agricultural supply. Without development of additional water, the State's irrigated agricultural acreage (1,249,581 acres in 1958) will shrink substantially as urbanization and industrialization proceed.

Since approximately 68 percent of Arizona's total water supply is pumped from underground, investigations of the quantity and movement of such water are of great importance. No underground lakes or subsurface free-flowing rivers are known to exist in Arizona. Apparently water moves slowly through gravel, sand or clay strata to alluvial-fill valleys, where it has remained stored, except for natural outflow, for centuries until tapped by wells.

To produce the amount of water needed for irrigation of crops and for domestic and industrial use, these underground reservoirs have been pumped at an increasing rate, particularly in the period after World War II.

Geologists estimate the overdraft (pumping in excess of recharge) on these underground sources of water to be about 3 million acre-feet annually, of which about 300,000 acre-feet is for municipal and industrial use.

While accurate estimates of the length of time this overdraft pumping can be continued are not available, it is evident from the constant fall of the water table and an increase in salts content in some pump areas that there is a limitation placed upon this source by both quantity and quality at some time in the future.

The quality of ground water is likely to be a limitation upon agricultural uses before the supply becomes a limiting factor in some areas.

Water from this source, where it is available, can be expected to be satisfactory, with processing, for domestic and most industrial uses for a much longer period. both from the standpoint of quality and cost of production.

Realistic planning for the future water needs of Arizona include elimination of this overdraft on ground water plus the amount of new water needed to meet the requirements of population and industrial growth.

On this basis, by the year 1980 Arizona will need approximately 3,500,000 additional acre-feet of water annually over and above its present use.

Surface water

Stored surface water annually available to Arizona is about 2,100,000 acre-feet. Six dams on the Salt and Verde Rivers provide storage of water for delivery to the Salt River Valley at Granite Reef diversion dam of almost 600,000 acre-feet.

Coolidge Dam on the Gila River in Pinal County stores water for delivery at Ashurst-Hayden diversion dam. Only about 78,000 acre-feet could be diverted in 1957.

In the Safford Valley area about 70,000 acre-feet are diverted.

The largest area served mostly by surface water is in Yuma County, where Colorado River water is available. Contracts for delivery of stored water from Lake Mead have been made by various districts and the Bureau of Reclamation. Annual diversion is about 1,300,000 acre-feet of water in Yuma County.

The remaining 50,000 acre-feet are diverted by numerous smaller diversion facilities throughout the State.

Recreation and pollution

The use of water as a means of recreation must be recognized and provided for within the limitations set by the geography and climate of Arizona. Fortunately, this is entirely feasible and is demonstrated within the framework of constructed reclamation projects in the State.

In addition to the many developed and potential recreation areas and facilities along the Colorado River, the six dams and reservoirs on the Salt and Verde Rivers provide a possible 28,000 surface acres of water for fishing, boating, and other recreational uses of water. Other water control structures throughout the State provide additional water-recreation opportunities.

All future reclamation projects planned in Arizona should and will give adequate emphasis to the nonconsumptive use of water for recreation.

The necessity for conserving water dictates a policy generally of utilizing fully for recreation the water in reservoirs built to serve also the domestic and agricultural needs of the State.

Closely related to recreational uses of water is the problem of stream and lake pollution. It is not yet a critical problem in Arizona, but in some areas of heavy recreational use there are indications of what must be faced in the future. Because so large a proportion of this use of water for recreation is upon lands owned by or controlled by the U.S. Government, Arizona can only hope that Federal planning and policing will minimize the problem of water pollution.

Because Arizona does not encourage industries which use large amounts of water, the disposal of industrial manufacturing waste products in water is not currently a problem.

Phoenix and Tucson, the State's two largest cities, have sewage treatment plants which discharge water that is utilized on a limited scale for irrigation of nonfood crops.

Planning for the future

With all of its perennial internal surface water sources utilized, the only remaining surface water possible of utilization in Arizona is the Colorado River. This interstate river flows for approximately 700 miles either along the border of or completely within Arizona. Use of its waters is regulated by the Colorado River Compact, the Boulder Canyon Project Act, the Mexican Water Treaty, and the California Statute of Limitation. The precise allocation of water to its users has, however, been the subject of long controversy over interpretation.

Arizona contends that it has a right to a minimum of 2,800,000 acre-feet annually from the mainstream of the Colorado River, plus half of any surplus which may exist.

The central Arizona project is a plan, engineered and found feasible by the U.S. Bureau of Reclamation, to bring 1,200,000 acre-feet of Colorado River water into the central part of Arizona, including Maricopa, Pinal, Pima, and Graham Counties. This water would supplement the existing surface water supply for presently irrigated farms and municipal use. No new lands are to be brought under irrigation. This project is needed as it has been several years since Arizona obtained the Wellton Mohawk project in Yuma County, this being the last new land brought into production in Arizona as a result of a Federal reclamation project.

Arizona is currently engaged in a suit against the State of California in the U.S. Supreme Court to clear its title to what it contends is its rightful share of Colorado River water.

Should the court decision in this suit make legally available to Arizona an amount of water sufficient to make the central Arizona project feasible, construction of a dam or dams on the river to generate hydroelectric power will be necessary. Such power will, as in the case of all reclamation projects, contribute to the repayment obligation of the construction through the sale of power in a market that can readily absorb generating capacity.

This project water from the Colorado River will then be available to an area of the State which supports 75 percent of the State's population, most of its manufacturing plants, and two-thirds of its irrigated farm acreage.

While the flow of perennial rivers and streams is for practical purposes completely controlled and utilized in Arizona, heavy summer storms frequently produce flood runoff in desert channels which are uncontrolled by dams. Much of this water is lost to evaporation as it spreads out in the desert or is transpired by saltcedars and other worthless vegetation.

The University of Arizona, in cooperation with other agencies of the State and Fdeeral Governments, is currently engaged in a research program to determine the feasibility of recharging the underground reservoirs with this runoff by means of wells and other methods.

Successful application of this principle of ground water recharge offers valuable opportunity to add to Arizona's water supply.

A considerable amount of research is also being conducted in Arizona to determine the possibilities of increasing water supply through management of the watershed lands.

Although Arizona received about 80 million acre-feet of precipitation annually, heavily concentrated in mountains and high plateau of the northern half of the State, only about 10 percent of it can be beneficially used under present conditions. About 4,200,000 acre-feet are used by timber and forage crops; 1,500,000 acre-feet penetrate the earth far enough to recharge ground water.

About 2,300,000 acre-feet are recovered and stored in surface reservoirs.

Transpiration by nonbeneficial plants and evaporation dissipate the remaining 90 percent of precipitation.

If watershed research evolves methods of management which can turn even a small percentage of this lost precipitation to beneficial use, the contribution to Arizona's economy will be invaluable.

Another potential source of "new" water for Arizona is the unmeasured amount of saline or brackish water underlying fresh water in some of the State's major ground water basins. Desalination of local brackish ground water may be economically practical in the future as a method of supplementing domestic water supply in some areas.

Although still in the realm of scientific theory, progress is apparently being made in the development of techniques for increasing rainfall. The Institute of Atmospheric Physics at the University of Arizona is working in this field, and it appears reasonable to hope for practical applications of cloud seeding. Coupled with improved watershed management practices to increase the percentage of precipitation put to beneficial use, artificially induced rainfall offers great possibilities for improving Arizona's water supply situation.

Finally, there is a great potential in eventual regional water planning. An interstate geopolitical approach to water problems of the family of Western States will be dictated by economic necessity in the future as population, industry, and irrigation agriculture continue to expand.

Islands of extreme water deficiency are weak spots in both marketing of products and production of goods. They can be eliminated by engineered redistribution of water surpluses which do exist in the western region.

Planning of this type calls for recognition of the interdependence of the economics of the Western States, and a brand of water statesmanship which rises above provincialism. Arizona looks to the time when it will import water from areas of surplus to benefit the economy and the people of the West and the Nation.

ARKANSAS

STATE OF ARKANSAS,
OFFICE OF THE GOVERNOR,
Little Rock, September 25, 1959.

Senator ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

DEAR SENATOR KERR: This is in reference to your letter of June 23, 1959, in which you request that your committee be furnished with information regarding the water problems of our State, both present and anticipated between now and 1980.

I have conferred with all agencies of our State government which are concerned with water problems, and am attaching a summary of the statements from each. These statements have been made as brief as possible, in order not to exceed the 10-page maximum which you requested. You will note that certain water problems are mentioned by more than one agency, and it is thought that this might serve to give some indication as to the breadth of interest in these problems.

I am also enclosing two recent publications, "Arkansas Water Resources" and "Water in Arkansas," which contain considerable detailed information.

We appreciate the interest of your committee in the vital question of water resource problems, and if we can be of further assistance, please do not hesitate to call on us.

Most sincerely,

ORVAL E. FAUBUS, *Governor.*

ARKANSAS WATER POLLUTION CONTROL COMMISSION

1. Maintenance of minimum flow downstream from impoundments should be given consideration. There are instances where the economic development of an area may be retarded by the inability of a stream to assimilate additional industrial or municipal wastes at infrequent low flows. If a fixed minimum flow could be maintained by release of reasonable quantities of impounded water for dilution at these infrequent periods, stream loadings could be increased with no adverse effects to water users in many instances. Provision should be made so that release of dilution water would be included as a benefit in determining cost-benefit ratio of proposed impoundments.

2. Additional gaging and water quality stations are badly needed. It is obviously impossible to forecast the downstream effects of a known quality and quantity of waste on a stream of unknown flow and quality. There are too many variables involved to rely on educated guesses forever if water resources are to be fully developed. Interpretation of data already obtained from existing stations would be of utmost benefit.

3. Additional research on the changed character of impounded streams and the effects of pollutants before and after impoundage would yield most valuable information insofar as pollution control agencies are concerned.

4. Instrumentation in the water field generally has lagged industrial instrumentation sadly. Continuous monitoring of quality and flow becomes more desirable with each phase of development of water resources.

5. Information as to the probable type and degree of industrial development of drainage basins based on known resources would also be helpful in planning pollution control from the aspect of long-range developments of an area.

ARKANSAS STATE BOARD OF HEALTH

The water problems that exist at this time with regard to public water supplies are the declining water tables in certain areas of the State, as well as undesirable chemical qualities in some stratas (salt, iron, manganese, etc.).

Concerning surface waters, incomplete gaging records and chemical analysis records on tributary streams hamper accurate design and forecasting. Pollution problems are known to exist on both the Red and Arkansas Rivers as they enter the State and along certain stretches of stream in the Ouachita River.

Lack of data on radioactivity in streams could also be classed as a problem from the public health point of view.

In the next 20 years, one can forecast a great domestic use of water even reaching over 200 gallons per capita per day. If the increased industrial use can be predicted along the same lines, conservation of waters and classification according to priority usage can be envisioned. Domestic use must receive the highest priority at all times because of the health, happiness, and well-being of humans involved.

Increased industrialization can only lead to increased deterioration of water quality unless properly controlled now.

It is felt that there is urgent need for study to ascertain the residual effects upon our water resources of the more and more widespread use of chemicals such as insecticides, defoliants, and those used for brush and weed control. It should be learned whether there is a cumulative effect from repeated use of these materials which might be harmful to public health.

ARKANSAS GAME AND FISH COMMISSION

The first concern of the game and fish commission pertaining to planning for water management for the next 20 years is as follows:

1. To see that the importance of fish and wildlife is considered along with all other water uses. We, of course, feel that fish and wildlife is as important as any other use, with the possible exception of water for domestic uses. It certainly is as important as water for irrigation or industrial supply.
2. To see that the fish and wildlife habitat is protected. Any water which is so heavily polluted or any water which is needlessly drained away to the point that fish and wildlife suffer represents, in our opinion, a great waste of a great resource.
3. To assure that the general public has the right to enjoy the benefits of fish and wildlife that may be present on any water area that may result either wholly or partially from the expenditure of public funds.

ARKANSAS INDUSTRIAL DEVELOPMENT COMMISSION

It is believed the time has come in the United States when we can begin to project the growth in the Nation and particularly in Arkansas on the basis of how much water can be made available at individual points for the support of population, industry, and agriculture. For several years, particularly here in Arkansas, we have felt the size of dams and reservoirs should be established on the reasonable amount of water that can be stored in the area rather than trying to project the particular industries or the number of industries that will be coming into the area if water is available. In other words, the conclusion cannot be drawn that if water is available in necessary amounts, the industries will be inclined more and more to grow into it. Also, when the occasion arises such as it did at Beaver Dam when everyone tried to estimate the size and type of industries which might come into the area, we think much good would be served if a realistic approach could be used on the basis of the maximum dam that should be built from an engineering and hydrological standpoint and then assigning to the water districts the cost of the dam in accordance with its height above what would be needed for flood control, power generation, etc.

It is believed future population and industry will gravitate to within the economical distribution of the water system built to serve the area from the storage provided. Since it is not expected that the Corps of Engineers or other agencies of the Federal Government will accept this approach, we are preparing to suggest the industries which might be expected to come into the particular area because of their topographical, population, and transportation characteristics.

We want to emphasize that the industrial development commission is only interested in the water potentials that remain for industrial use after the uses have been planned and managed for the support of population, agriculture with its irrigation and for the support of wildlife in the streams and on the land which is felt by our industrial development program to be vital considering the support of a happy society and to support the recreational and good living to which all employees in manufacturing plants are entitled and must have for effectiveness in their work.

We emphasize that we are most interested in the preservation of the excellent recreational facilities for fishing and hunting in Arkansas. We are most eager to protect the purity of the water as it is put back into the Arkansas streams so that other industries further down can be located to utilize that water.

ARKANSAS PUBLICITY AND PARKS COMMISSION

There is, at present, no greater attraction for tourists and the vacationing public than water—whether it be a clear, unpolluted mountain stream, a large lake, or a reservoir. Our parks with the heaviest use all are located in areas that afford water for boating, skiing, swimming, or fishing. The use of these areas has increased from around 250,000 visitors in 1957 to better than 1 million in 1959 and when we figure the value of each tourist in our State, we can readily see that the streams and lakes have exerted the greatest attraction for tourists. A multi-million-dollar attraction to us, we need all these we can possibly have unpolluted and clear. This is the great drawing potential we have to offer.

As so many of our streams are now polluted, great effort is needed to eliminate this. With this accomplished, we feel our tourist business will continue to expand.

ARKANSAS GEOLOGICAL AND CONSERVATION COMMISSION

Irrigation

Although all of Arkansas lies in the humid climatic zone and normally rainfall averages about 50 inches annually over the State, periods of drought occur even in years of average or above-average precipitation. Drought periods are considered to be any period of 20 days or more with less than 1 inch of precipitation and not more than one-half inch of precipitation occurring in any 10-day period. Periods of drought exceeding 50 days are not uncommon and may be expected during July, August, and September of any year regardless of the magnitude of spring precipitation.

Although irrigation had its beginning in Arkansas in 1904, general crop irrigation did not come into wide acceptance until the advent of World War II when farmers began to look for a means whereby they could produce greater yields. Surface water supplies have not been extensively used. Irrigation by pumping of ground water was developed because it presented the cheapest and most readily available water supply and could be developed with relatively small capital investments. This proceeded in the absence of accurate knowledge of the amount of water that could be safely withdrawn from the aquifer year after year without depleting the supply. It has already reached the point where pumping exceeds the safe annual yield and ground water levels are declining. The water table in the Grand Prairie area has been depressed at the rate of nearly 1 foot per year over an area of 700,000 acres during the past 50 years of pumping, and recharge has been negligible. It is believed that a similar situation will occur nearly everywhere in the Mississippi Delta and that ground water eventually will be exhausted.

Some study has been given to the possibility of recharging the ground water aquifer, but this has not proceeded to the point where it is possible to determine its feasibility.

Because of the high average rainfall in Arkansas, there is an abundance of surface water. It is estimated that the major rivers of Arkansas discharge a total of about 80 million acre-feet of water annually at the points where they leave the State. In general, however, the streamflows are at a minimum at the time that the need for irrigation water is at a maximum.

Arkansas follows the riparian doctrine with respect to use of water. It does not have a water code recognizing the doctrine of appropriation, in which the first in time is first in right, or recognizing rights to divert water to land which is not contiguous to the stream. Also there is no code concerning ground water, nor is there established an order of precedence in the use of water as between domestic, irrigation, power, etc.

Potential storage of water for beneficial uses in Corps of Engineers multiple-purpose projects

In accordance with provisions of title III of the Flood Control Act of 1958, commonly referred to as "The Water Supply Act of 1958," authority was granted for the addition of storage in Corps of Engineers projects for purposes other than flood control and power.

Arkansas has located within its boundaries a relatively large number of flood control lakes. Some of these are completed and in operation, others are under construction, and still others are in the planning stage while another category has received authorization from the Congress but no further actions have been taken in connection therewith.

In order to participate in the benefits which this action of the Congress provided, the Arkansas State Legislature has enacted suitable legislation. This legislation (act 114 of 1957) permits the organization of regional districts extending beyond county lines if necessary and provides for the necessary financial provisions which will permit compliance with the provisions of title III.

These districts have the authority to develop the required local assurances for the provision of storage in Corps of Engineers multiple-purpose reservoirs for municipal and industrial waters authorized in the Federal legislation. These districts may use the water in these storage areas for beneficial uses, may distribute this water by the building of pipelines, and may contract with municipalities and industries for the purchase of this water.

One such district of this type has already been organized in the southwestern portion of the State. Three other districts are in the process of being formed in order to permit the full utilization of this State legislation for beneficial water uses. It might be desirable to restudy all Corps of Engineers installations of a multiple-purpose character, whether completed or still in the planning stages, to determine if any part of the existing storage might be allocated for domestic and industrial uses or some mutually agreeable financial arrangement. Undoubtedly, this would require some new legislation.

Tremendous volumes of water are in storage within the borders of the State of Arkansas and additional storage of great quantity will become available upon the completion of presently contemplated and initiated projects, the principal one of which is the Arkansas River navigation project.

Generally speaking, the Arkansas problem with respect to the projects mentioned above, is a full and complete usage of water in storage. Of course, the fact remains at the present time that the potential beneficial uses for such waters are far less than the waters available. This of course, is a favorable condition, but again the fact remains that when demand arises for these surplus waters it will be desirable to have legal authority at both the Federal and State levels for the utilization of such waters. The prime purpose of most of the projects in Arkansas to which we have referred has been the control of floods and the incidental generation of power. Both of these functions have been admirably fulfilled within our State, and we now see the possibility and the probability of further utilization of these structures and the impounded waters for the further economic advantage and growth of the State of Arkansas.

Topographic mapping

Complete coverage with adequate topographic maps is necessary for a comprehensive study of water resources, either surface or underground. Only 25 percent of Arkansas has satisfactory mapping. The remainder of the State has small-scale mapping more than 50 years old, more recent maps which are not up to present standards, or in the case of 10 percent of the State's area, no topographic maps at all.

CALIFORNIA

STATE OF CALIFORNIA,
DEPARTMENT OF WATER RESOURCES,
Sacramento, November 20, 1959.

Hon. ROBERT S. KERR,
Chairman, U.S. Senate Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

DEAR SENATOR KERR: Please accept my apology for the delay in submitting the enclosed statement which I promised your committee at the October 15, 1959 meeting in Sacramento.

This statement has been prepared in conformance with your "General Outline of Proposed Procedures" and supplements my presentation to your committee in Sacramento. The reference documents, which contain detailed information, are being forwarded by parcel post.

The enclosed paper, together with my earlier statement, constitute our formal presentation.

If you desire further information, we would be pleased to assist you.

Very truly yours,

HARVEY O. BANKS, *Director*.

Enclosure.

STATEMENT OF THE CALIFORNIA DEPARTMENT OF WATER RESOURCES

SUMMARY STATEMENT ON THE WATER PROBLEMS OF CALIFORNIA AND CURRENT PROGRAMS FOR THEIR SOLUTION

This statement has been prepared pursuant to the request of the Select Committee on National Water Resources of the U.S. Senate. It consists of a series of concise, factual statements on the specific subjects set forth in "General Outline of Proposed Procedures," furnished as an enclosure to the letter of June 23, 1959, from Senator Robert S. Kerr, chairman.

I. STATEMENT OF THE EXISTING SITUATION AND PRESENT TRENDS

A. Summary of water resources available

The estimated mean seasonal natural runoff of California streams, computed on the basis of records available for the mean climatic period 1894–95 to 1946–47, is approximately 71 million acre-feet. Of this amount, some 72 percent, or slightly over 51 million acre-feet, is produced in the northern one-third of the State, and 2 percent, or about 1,400,000 acre-feet, is produced in the south coastal and Colorado Desert areas. During the 52-year period, the maximum seasonal runoff, 135 million acre-feet occurred in 1937–38, and the minimum, 18,300,000 acre-feet, in 1923–24. The average seasonal runoff during the critical 10-year dry period from 1927–28 to 1936–37 was only 69 percent of the 53-year mean and the actual runoff during each year of that period was less than the longtime mean.

See pages 38–39, Bulletin No. 1, "Water Resources of California."

B. Statement on withdrawal and use of water

No estimates have been made of the total withdrawal of water supplies from streams and underground sources in California. Estimates have been made, however, of the quantity of water required for artificial delivery to the various water service areas throughout the State. This quantity, termed "water requirement," is that sufficient to provide for beneficial consumptive use of applied water plus the irrecoverable losses (seepage, channel evaporation, return water, sewage outflow, etc.) incident to such use.

It is estimated that by 1960 the water requirement of urban areas will be about 3,010,000 acre-feet; and the requirement for agriculture will be about 21,700,000 acre-feet, or a total of 24,700,000 acre-feet. About 50–60 percent of the irrigation delivery requirement is beneficially consumed while the consumptive use of urban and industrial service varies from less than 10 to 100 percent of the delivery requirement, depending upon the geographical location, type of use, and the method of waste disposal.

It is estimated that under conditions of full development of the State's land and other resources, the water requirement will increase to an amount in the order of 55 million acre-feet annually. To meet this demand, it will be necessary to develop surface storage reservoirs and utilize the underground basins to the maximum extent possible. (See Bulletin No. 2, "Water Utilization and Requirements of California," vol. I, pp. 226–227.)

C. Fundamental problems

The fundamental physical problem of water resources development in California is the extreme geographic and seasonal maldistribution of the State's water resources in streams and underground basins, as related to the location and seasonal distribution of the major portion of the total requirements for the use thereof. With approximately 72 percent of the water resources occurring in the northern one-third of the State, and approximately 75 percent of the annual demand, present and future, found in the southern two-thirds of the State, the problems of conservation and distribution of water supplies for beneficial uses are readily apparent. Interposed between the areas of supply and demand are great distances and formidable topographic obstacles. These problems, of course, are complicated by the relative timing of the occurrence of supply and demand. About 80 percent of the supply occurs as rain and snow during the period from November to April, while the major requirement, particularly for agriculture, occurs in the summer and fall. The storage problem is further complicated by the occurrence of major rainfloods during the winter period and snowmelt floods in the early summer, before agricultural demand has developed appreciably. The remaining dam and reservoir sites pose difficult design and construction problems and storage therein will be comparatively expensive. (See Bulletin No. 3, "The California Water Plan.")

D. Ground-water problems

The underground water resources of California are being subjected to severe overdraft conditions. The present overdraft on these ground-water basins is estimated to be approximately 5 million acre-feet seasonally. This has resulted in the accelerated recession of water tables in many areas, with consequent excessive costs for pumping, for deepening of wells and lowering of pumps, as well as deterioration in quality of the ground water. The economic limit for pumping of ground water for agricultural problems is rapidly being approached in some areas, such as Kern County.

An extremely serious problem is the intrusion of sea water into overdrawn coastal ground-water basins. This situation has occurred in several of the major coastal ground-water basins with resultant large economic losses.

Connate water (fossil sea water) is a threat to inland ground water basins that are being overdrawn.

As the demand for water increases, the problems of ground-water basin overdraft increases. This condition exists in many areas that do not have adequate surface water supplies. (See ch. 2, p. 21, and ch. 4, pp. 206–210, Bulletin No. 3, "The California Water Plan," and Bulletin No. 63, "Sea Water Intrusion in California.")

E. Water use for pollution abatement

The problem of the maintenance of a satisfactory quality in the surface streams and ground-water reservoirs of California is exceedingly important and difficult in view of the limited water supplies available to meet the projected full development of the economy of the State. At the present time there are few, if any, cases of severe pollution in the State. However, the threat is ever present and growing because of rapidly increasing population and industrial development. The low flows remaining in the lower reaches of streams during late summer and fall months intensify the problem.

While there is some capacity to absorb waste discharges in the surface waters and ground-water basins of the State, the fresh-water resources of California cannot be utilized extensively for this purpose because of the increasing demands for agricultural, domestic, municipal, and industrial purposes. The maintenance of a suitable habitat for fish and wildlife, provision for water-associated recreation, and esthetic considerations, are of great importance to the State's rapidly expanding population. For these reasons, studies of alternative methods of waste disposal, not involving dilution in fresh-water sources are under intensive study. At the same time, the State's coastal saline waters must be adequately protected from pollution in order to prevent damage to marine life and to the recreational use of those waters. (See ch. 2, p. 18, and ch. 3, p. 33, Bulletin No. 3, "The California Water Plan," and Bulletin No. 62, "Recommended Water Well Construction and Sealing Standards, Mendocino County.")

The State and regional water pollution control boards, which are separate State agencies, are responsible for prevention and abatement of pollution. A statement incorporating policy recommendations transmitted to the assembly subcommittee on bay and water pollution, under date of May 21, 1958, by the directors of the State departments of public health, fish and game, agriculture, natural resources, and water resources, all of whom are members of the State water pollution control board, is attached, as is a pamphlet outlining the current pollution control laws.

II. PROJECTIONS OF FUTURE DEMANDS FOR WATER AND WATER-RELATED ACTIVITIES CONSIDERING RELATIONSHIPS OF AVAILABILITY AND COSTS

A. Population projections

The presently projected future population of California for 1980 is estimated to be about 28 million persons, nearly double the present population. A discussion of population growth projections will be found in Bulletin No. 78, "Preliminary Summary Report on Investigation of Alternative Aqueduct Systems to Serve Southern California," on page 15.

B. Municipal water use

An extensive discussion of municipal use of water will be found in chapter 2, Bulletin No. 2, "Water Utilization and Requirements of California." From studies made in preparing this bulletin, the estimated ultimate requirement for urban and suburban areas would be about 8 million acre-feet annually. The experience since this study was made indicates that estimate may have been conservative. Urban water supplies are also discussed in Bulletin No. 61, "Investigation of Alternative Aqueduct Routes to San Diego County," in chapter 2, pages 58–62, 66–75, and 88–101, and in Bulletin No. 78.

C. Agricultural use of water

The growth in demand for agricultural water supplies is extensively discussed in Bulletins Nos. 2 and 3. It is also discussed in various reports of investigations relating to smaller geographical divisions of the State, the most important of which is perhaps Bulletin No. 58, "Northeastern Counties Investigation." The projected ultimate demand for agricultural water supplies in California, as set forth in Bulletin No. 2, page 226, amounts to about 37 million acre-feet annually. The development of this estimate is thoroughly discussed in that bulletin. Improved farm equipment and new methods of applying water, making possible irrigation of more land, will significantly increase this figure.

D. Water needs of industries (including atomic)

Industrial needs have not been considered as a separate item. They have been considered in combination with urban and suburban requirements. Determination of requirements made in 1950, indicated ultimate requirement for urban, suburban, and industrial uses would be 8,300,000 acre-feet annually. In view of the accelerated rate of industrial development in the State since 1950, a study now would probably indicate a much greater requirement for these purposes. The expanding population of the State makes it necessary that an adequate water supply be made available for industrial growth.

Studies have not been completed to determine future needs of industry utilizing atomic energy processes.

E. Electric energy

The demand for electrical energy is an important aspect in the plans for development of the water resources of the State. Current estimates prepared by Pacific Northwest—"California Inter-Connection Study, Power Requirements and Resources," State of California Federal Power Commission, San Francisco regional office, and Bureau of Power indicate that by December 1960, the coincidental peak demand will be 11,544,000 kilowatts with annual energy of 63,080 million kilowatt-hours. Of this requirement, the State will require 9,000 kilowatts with 78 million kilowatt-hours for pumping in their water development program. By 1980, the corresponding requirements will have increased to 34,712,000 kilowatts demand with 201,184 million kilowatt-hours energy, and for State pumping 197,000 kilowatts with 5,091 million kilowatt-hours of energy. In view of the enormous increase in demand for power, hydroelectric development must be continued.

The cost of producing electrical energy by steam plants has reached the stage of being competitive with hydroelectric energy. It is reasonable to assume that atomic-electric plants will, in the future, also produce power at a competitive price. It is well known that steam plants operating to supply the base power load in conjunction with hydroelectric plants to supply peak loads is an effective combination. This is also expected to be true of atomic plants in conjunction with hydroelectric plants. It is also well known that hydro units have several inherent advantages, including outstanding reliability and operating flexibility, over steam units, especially the modern high-efficiency units, for high-value peaking service.

As stated in paragraph III–A of this paper, development of additional water supplies by conventional methods to meet future demands will be costly. Maximum power development, commensurate with water conservation, is required to keep the cost of water to a minimum as well as to meet the increased demand for power. Water conservation must not be sacrificed in any degree for the sake of developing power.

F. Navigation

The principal streams in the State where navigation is an element to be considered are the Sacramento and San Joaquin Rivers. The Central Valley project adequately provides this requirement on these two streams. No further problems in this respect are anticipated.

G. Flood control

In the Central Valley, damaging floods inundate large areas of highly productive agricultural land and interfere with important industrial operations. In the coastal regions highly urbanized areas are subjected to flooding and extensive damage.

The Corps of Engineers in their "Report on Floods of February–June 1958 Sacramento-San Joaquin-Tulare Lake Basins, Calif.," estimated the preventable damage by authorized, but not completed, Corps of Engineers reservoir projects in the area. These projects and the estimates are presented in the following tabulation:

Estimated flood damages preventable by project (February–June 1958)

Name of project:	
Oroville Reservoir [1]	$250,000
Black Butte Reservoir	550,000
Iron Canyon Reservoir	2,500,000
Sacramento River, major and minor tributaries	750,000
Sacramento River, Chico Landing to Red Bluff	50,000
Middle Creek project	300,000
Bear Creek project	600,000
New Hogan Reservoir	300,000
Lower San Joaquin River levees	550,000
New Melones Reservoir	300,000
New Don Pedro Reservoir	400,000
Kings River project	50,000
Upper San Joaquin River project [1]	1,200,000
Success Reservoir	1,100,000
Terminus Reservoir	1,300,000
Total	10,200,000

[1] Being constructed by State of California.

Flood control projects in other areas of the State that would have substantially reduced the damage incurred in the 1958 floods are listed starting on page 38, "California Floods of 1958."

In most instances, by combining flood control and conservation into one project, both functions are improved.

H. and I. Water recreation—Fish and Wildlife

Recreation and enhancement of fish and wildlife resources are considered as important project functions. They should not be relegated as merely incidental to the primary functions of a project. The recreational potential of all water development projects should be developed to the maximum feasible extent, as the State of California is doing in its water development program. Likewise, provision should be made for the enhancement of fish and wildlife resources to the maximum extent feasible. These aspects should be taken fully into account starting with the planning phase and not left for consideration after the works are built. Costs allocated to these purposes should be considered nonreimbursable insofar as the water and power users are concerned.

The California State Legislature, in its last session, enacted legislation requiring that consideration be given to fish and wildlife in water development reports submitted for their consideration and that the State water rights board give consideration to water required for recreation and for preservation and enhancement of fish and wildlife resources, when in the public interest, in granting water rights. The legislature also provided for grants by the State for cost of a local project, allocated to recreation or enhancement of fish and wildlife if those functions are incidental to the primary purpose of the project and the functions are of statewide interest. Assembly bills 140 and 141 and Senate bill 425 are attached. Senate bill 1106 also provides funds for these purposes.

J. Trends in use of water for waste disposal

The use of the naturally occurring water supplies of California for waste disposal must be limited to the maximum extent to retain the natural water supplies for consumptive use purposes. Much of the waste disposal from the coastal areas is discharged directly to the ocean. Preparation of plans for an extensive drainage system from the inland area of the Central Valley to carry waste water from that area into saline tidal water is in progress.

Considerable progress has been made toward developing a feasible method of disposing of industrial wastes through the cooperative efforts of industry, water pollution control agencies, and other technical agencies of the State. A detailed discussion of this subject is contained in the attached paper entitled "Disposal of Oilfield Brines in the Central Valley of California."

Operation of ground water basins is a very important factor in utilizing water resources. The quality of these waters must be preserved. The sources of pollution present many problems but degradation of these underground reservoirs can be prevented if corrective measures are taken at an early date and diligently followed. Water project developers have a responsibility here that is not always recognized and accepted. For a detailed discussion see attached paper, "Water Quality Considerations in Ground Water Basin Operation."

III. MEANS OF MEETING FUTURE DEMANDS

A. Conventional methods of adding new supplies and costs thereof

It has been demonstrated that the future demands for water can be met by conventional methods. The California water plan, published in 1957, provides a general long-range guide for accomplishing the massive alteration of nature's scheme of supplying water. A State water project construction program is called for to supplement local and Federal efforts. The job is beyond the scope of any one of these agencies.

There are legal, financial, and political considerations that pose problems in launching a State water project construction program. They can be overcome by the coordinated efforts of all concerned.

From an engineering standpoint, the physical difficulties of the State's water problem can be overcome. By constructing dams and reservoirs to conserve winter and wet year flows and by constructing aqueducts, pumping plants, and distribution systems to convey the water and make it available for use when and where it is needed will accomplish this.

Development will be costly. Based on 1957 price levels, the ultimate cost would be about $12 billion. Unit cost of water under the initial project which is now under construction will be in the $50 per acre-foot range. This does not include cost of local distribution.

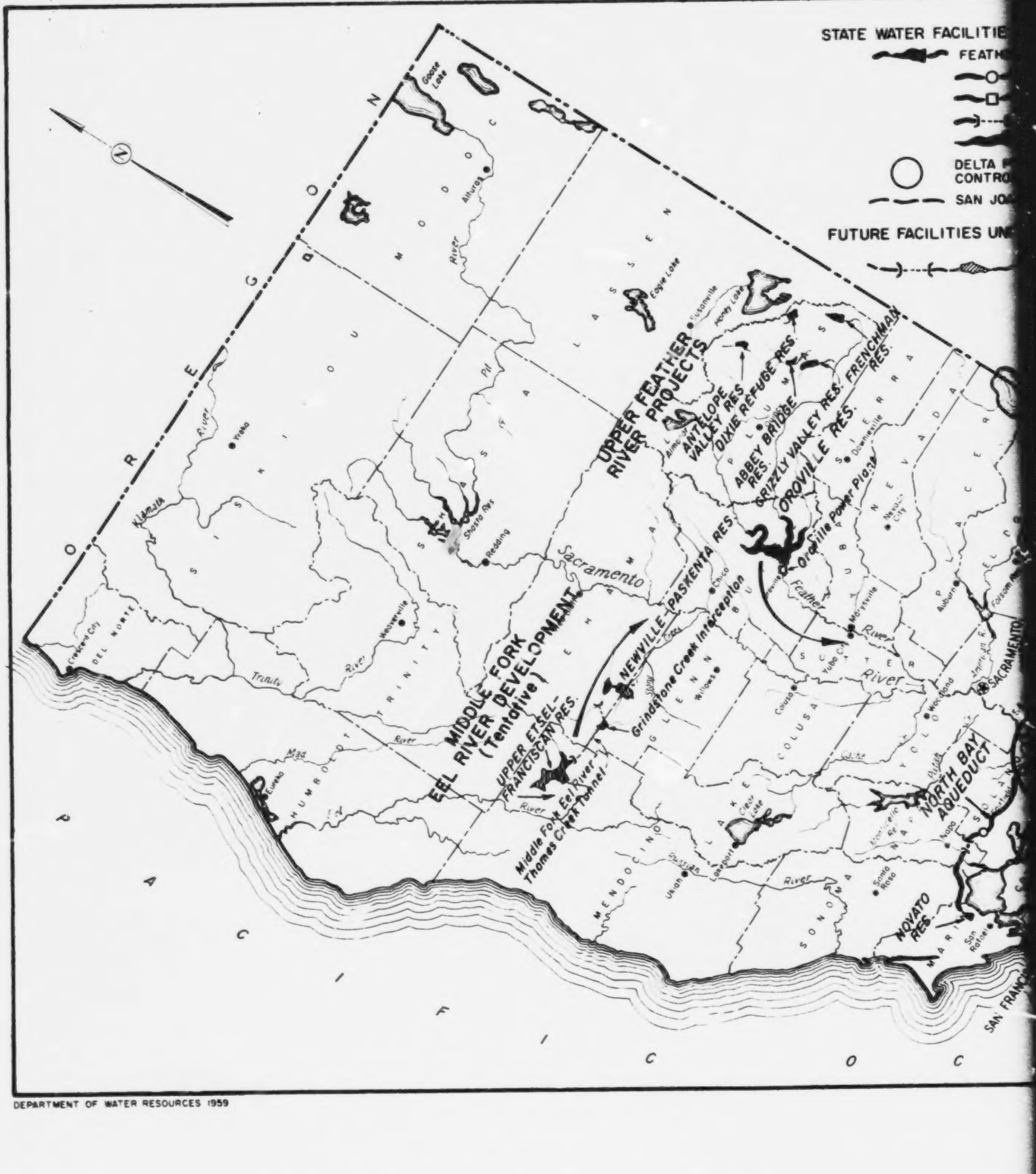
B. Vegetational management

The possibilities of increasing the water supply by vegetational management in the watershed is good. Where watersheds are covered with brush growth which has no value and it is possible to supplant this growth with grasses, more water is retained in the soil and the grass has a value as forage. Sufficient information is not available to supply a definite quantitative evaluation. More experimental research is required.

The U.S. Department of Agriculture, through the Soil Conservation Service, under Public Law 566, provides technical assistance to construct small projects for water conservation and watershed management. This program is very active in the State and provides a very necessary watershed management function.

Watershed management in the snow zone offers possibility of more efficient use of available water supplies. Research of this function is being conducted by the U.S. Forest Service through their Pacific Southwest Forest and Range Experiment Station. California is a cooperator in this program which includes management of timber to

18a


STATE WATER FACILITIE
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Yreka
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River
Pit River
Shasta Res.
Redding
SHASTA
LASSEN
Eagle Lake
Susanville
Honey Lake
UPPER FEATHER RIVER PROJECTS
ANTELOPE VALLEY RES.
DIXIE REFUGE RES.
ABBEY BRIDGE RES.
GRIZZLY VALLEY RES.
FRENCHMAN RES.
OROVILLE RES.
Oroville Power Plant
PLUMAS
SIERRA
Downieville
NEVADA
Nevada City
YUBA
PLACER
Auburn
Folsom
SACRAMENTO
Sacramento
TEHAMA
Chico
BUTTE
Feather River
Marysville
Yuba City
SUTTER
River
NEWVILLE-PASKENTA RES.
Grindstone Creek Interception
Stony Creek
Willows
GLENN
COLUSA
Colusa
Woodland
YOLO
Cache
MIDDLE FORK EEL RIVER DEVELOPMENT (Tentative)
UPPER ETSEL-FRANCISCAN RES.
Middle Fork Eel River-Thomas Creek Tunnel
TRINITY
Weaverville
Trinity
River
Crescent City
DEL NORTE
HUMBOLDT
Eureka
Mad
Eel
River
MENDOCINO
Ukiah
Russian
River
LAKE
Clear Lake
Lakeport
SONOMA
Santa Rosa
NAPA
Napa
Monticello Res.
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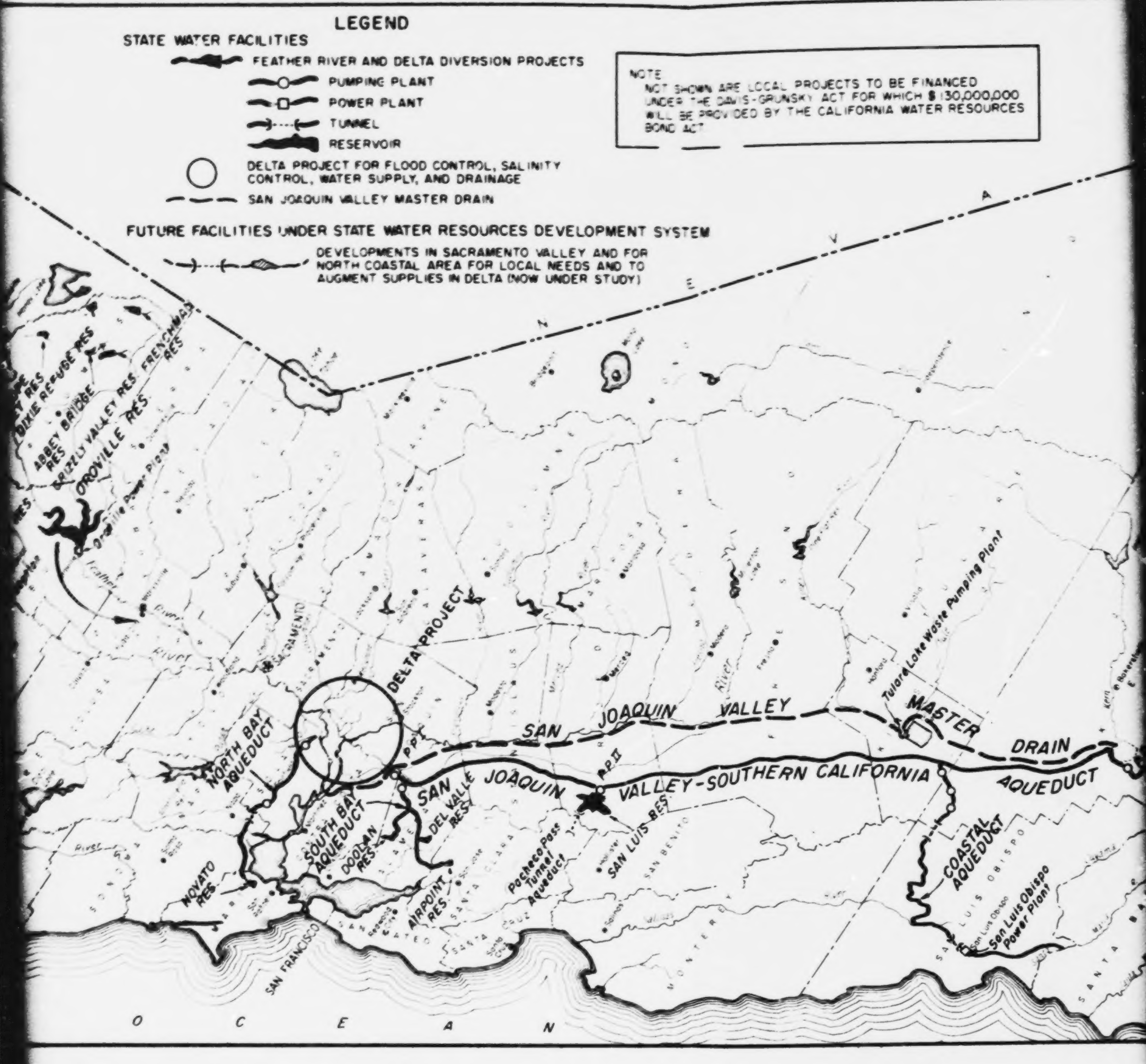
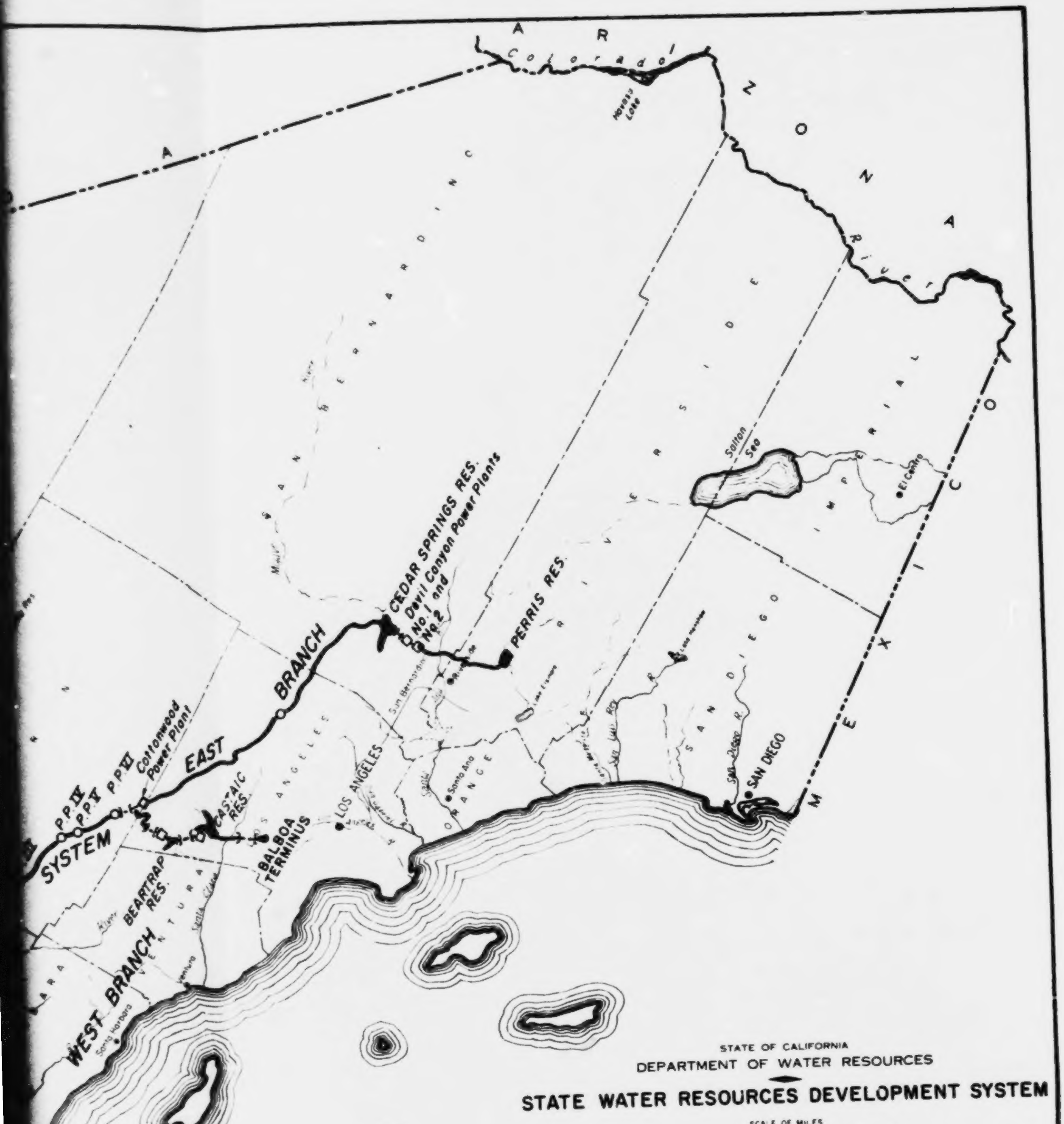
NORTH BAY AQUEDUCT
SOLANO
NOVATO RES.
MARIN
San Rafael
SAN FRANCI

DEPARTMENT OF WATER RESOURCES 1959


LEGEND
STATE WATER FACILITIES
FEATHER RIVER AND DELTA DIVERSION PROJECTS
PUMPING PLANT
POWER PLANT
TUNNEL
RESERVOIR
DELTA PROJECT FOR FLOOD CONTROL, SALINITY CONTROL, WATER SUPPLY, AND DRAINAGE
SAN JOAQUIN VALLEY MASTER DRAIN
FUTURE FACILITIES UNDER STATE WATER RESOURCES DEVELOPMENT SYSTEM
DEVELOPMENTS IN SACRAMENTO VALLEY AND FOR NORTH COASTAL AREA FOR LOCAL NEEDS AND TO AUGMENT SUPPLIES IN DELTA (NOW UNDER STUDY)
NOTE
NOT SHOWN ARE LOCAL PROJECTS TO BE FINANCED UNDER THE DAVIS-GRUNSKY ACT FOR WHICH $130,000,000 WILL BE PROVIDED BY THE CALIFORNIA WATER RESOURCES BOND ACT
N E V A D A
DIXIE REFUGE RES
ABBEY BRIDGE RES
GRIZZLY VALLEY RES.
FRENCHMAN RES
OROVILLE RES.
Oroville Power Plant
Feather River
River
SACRAMENTO
DELTA PROJECT
NORTH BAY AQUEDUCT
SOUTH BAY AQUEDUCT
NOVATO RES.
DOOLAN RES.
DEL VALLE RES.
AIRPOINT RES.
Pacheco Pass Tunnel Aqueduct
SAN LUIS RES.
P.P.I
P.P.II
SAN JOAQUIN VALLEY MASTER DRAIN
SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT
Tulare Lake Waste Pumping Plant
COASTAL AQUEDUCT
San Luis Obispo Power Plant
SAN FRANCISCO
O C E A N


ARIZONA
Colorado River
Havasu Lake
SAN BERNARDINO
RIVERSIDE
IMPERIAL
SAN DIEGO
ORANGE
LOS ANGELES
VENTURA
MEXICO
Salton Sea
El Centro
Mojave River
CEDAR SPRINGS RES.
Devil Canyon Power Plants No. 1 and No. 2
PERRIS RES.
EAST BRANCH
Cottonwood Power Plant
P.P. IV
P.P. V
P.P. VI
SYSTEM
CASTAIC RES.
BALBOA TERMINUS
BEARTRAP RES.
WEST BRANCH
LOS ANGELES
SAN DIEGO
San Diego R.
Santa Ana
Riverside
San Bernardino
Ventura
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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

STATE WATER RESOURCES DEVELOPMENT SYSTEM

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H. Effects of nuclear energy

If the cost of nuclear energy is reduced to the extent that it is competitive with conventional sources, it could be used for pumping water and conversion of saline water. While this is not expected in the immediate future, as previously stated, a scientific breakthrough could have a bearing on meeting the ultimate demand for water.

I. New technical methods of improving water supply methods

There are no technical methods of meeting water supply demands known or anticipated. Such developments are, of course, always within the realm of possibility, but to rely on such an occurrence for a water supply would not be advisable in view of the situation facing California.

The State has participated jointly with the Los Angeles County Flood Control District in developing a method of combating sea water intrustion by the injection of fresh water into water-bearing materials adjacent to the coast. This has succeeded in moving the saline wedge oceanward in a limited area. The county of Los Angeles has presently programed extension of the barrier lines of injection wells to cover a greater part of the intruded aquifers bordering Santa Monica Bay.

In the future, because of the limited surface storage capacity available in the State, it is proposed to use the tremendous storage capacity existing in the underground basins of California for the longtime cyclic storage of water supplies over drought periods and for reregulation of constant deliveries of imported water to the monthly demand schedules at terminal points of delivery.

IV. STATE OF CALIFORNIA WATER DEVELOPMENT PROGRAM

The State has been aware of the impending increase in demand for water, which has now become a reality. "The California Water Plan" is the result of a study of the State's water resources that was authorized by the State legislature in 1947. The study and report were 10 years in the making and were completed at considerable expense.

To implement State water development, legislation was enacted in 1959 to provide financing for such development on a statewide basis for the next 25 years. Facilities to be constructed with the financing provided are designated in the legislation. Provision is also made for $130 million to be used as State financial assistance to local projects. Nearly $100 million was appropriated to actually get the construction program moving.

The above method of financing will provide funds to construct the initial features of the California water development program. This development program combined with a continuing program of development by the Federal Government and local agencies should keep pace with the ever-increasing demand for water in the State. (See Senate bills 425 and 1106, paper entitled "California's New Water Program" and map entitled "State Water Resources Development System.")

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COLORADO

COLORADO WATER CONSERVATION BOARD,
Denver, Colo., February 25, 1960.

Hon. ROBERT S. KERR,
Chairman, Senate Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

DEAR SIR: At the request of Mr. Theodore Schad, this is to advise you that the testimony which I presented on behalf of this board before your committee on November 20, 1959, covered the matter of potential water development in the State of Colorado through 1980, and can be considered as Colorado's statement on this subject.

Respectfully yours,

FELIX L. SPARKS, *Director.*

STATEMENT OF THE WATER CONSERVATION BOARD OF THE STATE OF COLORADO TO THE SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES, NOVEMBER 20, 1959

This statement has been prepared by the Water Conservation Board of the State of Colorado, the agency of the State of Colorado which has the responsibility for preparing the State's response to Senator Kerr's letter of June 23, 1959. The general purpose of the board is to formulate and further a continuing State policy with respect to water-development programs and problems, both intrastate and interstate. Attached to this statement as table I is a condensed enumeration of the functions of the board.

TABLE I.—COLORADO WATER CONSERVATION BOARD

The following condensed enumeration of the functions of the board (created in 1937) and its composition, was written by the late Judge Stone, the first director of the board.

> (1) "To appraise and inventory the State's water resources and develop programs for their conservation, utilization, and control.
>
> (2) "To formulate and further a continuing State policy with respect to water development programs and problems, both intrastate and interstate.
>
> (3) "To promote water projects and in connection therewith conduct investigations, make surveys and studies, and review and make official State comments upon project reports of Federal agencies.
>
> (4) "To aid and collaborate with local affected interests and to consult with other interested State agencies and Federal agencies in all matters relating to the Federal water development program.
>
> (5) "To handle interstate water relations and problems, including the furnishing of engineering service to the Attorney General in interstate litigation over water; and to render aid and assistance engineering and otherwise, to negotiating and administrative compact commissions.
>
> (6) "And generally to aid in the conservation, beneficial utilization, development, and protection of the water resources of Colorado in the interest of the present and future welfare of the State and its citizens.

"The Colorado Water Conservation Board consists of 14 members. The Governor is an ex officio member and chairman. Other ex officio members are the attorney general, the State engineer, the director of the State planning commission, and the director of the Colorado Water Conservation Board. The remaining nine members are appointed by the Governor and serve for 3-year staggered, terms. Four of these members are appointed from western Colorado, four from eastern Colorado, and one from the San Luis Valley, in the upper Rio Grande Basin. Of the four members from western Colorado, one is appointed from the San Juan Basin, one from the Gunnison and Uncompahgre Basins, one from the main stem of the Colorado River, and one from the White-Yampa Basin area. Of the four appointed from eastern Colorado one is appointed from the Arkansas Basin, one from the South Platte Basin, one from the North Platte Basin, and one from the city and county of Denver.

"In order to carry on its work the Board maintains an engineering and legal staff. The executive officer of the board is the director, who is also responsible for representing the board and the State in various contacts with other States, with Federal agencies, and with water interests throughout the State. He is called upon to appear at various water hearings, including those conducted by committees of the Congress."

The members of the Colorado Water Conservation Board appreciate the opportunity to make this statement to the Senate Select Committee on National Water Resources. We feel that a basic inventory of the Nation's water problems is long overdue, and we are delighted that the U.S. Senate has taken the initiative to create this fact-finding committee.

In Colorado are found the headwaters of four of the major rivers of the West—the Platte, the Arkansas, the Rio Grande, and the Colorado. These rivers are the life arteries of the State of Colorado. These rivers or their tributaries are of similar importance to the majority of the States west of the Mississippi River.

Geographically, Colorado occupies a unique position within the continental boundaries of the United States. Waters originating in other States are in nature not available for use in Colorado. On the other hand, all of the surface waters of the State, excepting natural losses, are available by gravity to 18 other States. This itself would not be significant if it were not for the fact that by court decision and interstate compact we are compelled to deliver about 50 percent of our available surface water to other States. This latter observation is not in the nature of a complaint, but is illustrative of how the water resources of a given State may be depleted without internal use.

In Colorado, the use of water is governed by the appropriation doctrine. This doctrine is written into our Constitution and statutes and has been generally adopted throughout the Western States. As far back as 1900 the dependable natural flows of the Arkansas, Platte, and Rio Grand Rivers had largely been appropriated. Since that time millions of dollars have been expended in capturing floodflows, and millions more expended in transmountain diversions from the Colorado River.

The situation that we find ourselves in today is that we have already exhausted the surface water resources of three of our major river basins. Within the next 50 years the water resources of the Colorado River Basin will have become almost entirely exhausted. Our major problem today lies in developing our remaining water resources at a pace commensurate with our population increase. I am sure that this same statement has been made in every State in which this committee has visited.

Colorado's population is increasing at a rapid rate. According to the 1950 census, Colorado's population was 1,325,000. A projection of recent trends indicates a total population by 1980 of 2,600,000 for the State. This means an annual net increase of about 40,000 persons. This population projection does not take into account the definite possibility of a major shale oil industry in western Colorado which could add another half-million people to our population by 1980.

The most phenomenal growth in Colorado has occurred in the Denver metropolitan area, where a 54.5 percent increase in population has taken place in the past 9 years. The metropolitan counties of Arapahoe, Jefferson, and Adams have experienced a population increase of over a hundred percent in the past 9 years, with Adams County showing an astonishing 160 percent increase.

Water problems in Colorado are greatly compounded by the fact that the population distribution bears no relationship to the State's available surface water supply. Attached hereto is table II showing the population distribution by river basin and the corresponding available surface water supply for that river basin. These figures are shown in percentages of the overall State total and do not reflect the depletions by virtue of interstate compacts and Supreme Court decisions. In order to briefly summarize the water situation here in Colorado, I shall divide the State into it's four major river basins:

TABLE II.—*Population and surface water production in Colorado's major river basins*

[In percentages]

River basin [1]	Percent of State population [2]	Percent of State surface water production [3]
South Platte	60	9.6
Arkansas	24	6.9
Rio Grande	3	9.3
Colorado	12	68.0

[1] North Platte and Kansas River Basins are omitted. Although these basins produce about 6.2 percent of the State's surface water, geography, interstate compact, and Supreme Court decisions permit only local and limited use in Colorado. These areas contain less than 1 percent of the State's population.

[2] Based on 1950 census.

[3] Estimated average annual.

South Platte River Basin

The South Platte Basin is the most heavily populated area of Colorado. In this basin are found Denver and its metropolitan area. Based on the 1950 census, the South Platte Basin has about 60 percent of the State's population. However, the estimated water production in the basin is slightly less than 10 percent of the State total. The available water supply of the South Platte Basin was long ago exhausted. The disparity between the population and water supply in this basin is much greater at the present time and will continue to increase, since the State's greatest population growth during the past 9 years has occurred in this area. The population of the South Platte Valley has increased roughly by 300 percent during the past 30 years. New water supplies have been developed by transmountain importations from the Colorado River. However, there is a limit to the availability of Colorado River waters and the utmost conservation measures must be utilized in the basin if future growth is to be insured.

In the near future approximately 500,000 acre-feet of water annually will be exported into the South Platte Basin from the Colorado River Basin from two systems alone, the Denver municipal water supply system and the Colorado-Big Thompson project system. The Colorado-Big Thompson has to date been the major reclamation project in the State of Colorado with a total cost of approximately $159 million. The privately financed Denver municipal water supply expansion to divert waters of the Colorado River, now under construction and partially completed, will cost an estimated $183 million. Several important projects which would capture the small remaining amount of floodwaters and permit greater river regulation are now in the planning stage and in all probability will be constructed prior to 1980. The principal project in this category is the Narrows project on the South Platte River near the city of Fort Morgan which has already been authorized by Congress.

Projected expenditures for the South Platte Basin for water resource development through 1980 is estimated at $413,852,000. This amount can be broken down into expenditures of $232,125,000 for non-Federal funds and $181,727,000 from Federal funds.

Arkansas River Basin

The Arkansas River Basin in southeastern Colorado occupies second place in population total. In this basin are found two of Colorado's major cities, Pueblo and Colorado Springs. As is true of the South Platte Basin, industrial and commercial activities greatly exceed agricultural production. The Arkansas Basin contains about 24 percent of the State's population but only about 7 percent of the State's surface water supply. A significant portion of the flow of the Arkansas River must be shared with the State of Kansas.

Any appreciable population growth in the future will not be possible in the Arkansas Valley unless additional water resources are made available. One of the State's major reclamation projects, the Fryingpan-Arkansas, has long been planned to augment the already exhausted water supply of this area. This vital project is now awaiting congressional authorization. No Federal reclamation project has as yet been constructed for the benefit of the Arkansas Valley, although the John Martin Reservoir, constructed by the Corps of Engineers, has contributed greatly to the economy of the area. As is common with the South Platte Valley, rigid conservation measures must be undertaken for the maximum utilization of the available water supplies.

The Trinidad project, primarily for flood control, has been authorized for construction in the Arkansas Valley. This project will have a small amount of conservation storage.

Anticipated expenditures for water resource development in the Arkansas Valley through 1980, are estimated at $202,682,000. Of this amount, $194,269,000 is estimated as Federal expenditure and the remaining $8,413,000 as non-Federal expenditure.

Rio Grande Basin

In south central Colorado is found the San Luis Valley traversed by the Rio Grande River. Relatively isolated by the Continental Divide on the west and the Sangre de Cristo Range on the east, the San Luis Valley contains about 3 percent of the State's population and approximately 9 percent of the total surface water supply. However, under the terms of the Rio Grande compact, New Mexico and Texas make heavy demands on the Rio Grande River. Because of these demands there is a chronic shortage of available water in the valley. The economy of the valley is heavily agricultural and fluctuates in direct proportion to the annual precipitation. The valley itself is one of the most arid areas in Colorado and the average precipitation at Alamosa, the principal city, is only about 5 inches annually. There is little opportunity to increase the water supply of the area except from the application of conservation measures. Promising water salvage investigations are now being currently conducted by the Bureau of Reclamation. The specialized agricultural and livestock production of the San Luis Valley contributes greatly to the overall economy of the State.

Project expenditures for water resource development in the Rio Grande Basin through 1980 are estimated at $32,957,100. Of this amount, $32,380,000 is classified as a Federal expenditure and $577,100 as a non-Federal expenditure.

Colorado River Basin

The Colorado River drains all of that portion of the State of Colorado lying west of the Continental Divide. This is Colorado's major river and is one of the major rivers in western United States. The Colorado River produces about 68 percent of the State's total water supply but only about 35 percent of this amount is available for use in Colorado. The river produces on the average, in Colorado, about 11 million acre-feet of water annually. Under the terms of the Colorado River Compact and the Upper Colorado River Compact, about 3,900,000 acre-feet annually can be used in Colorado.

Western Colorado has an abundance of natural resources and a major livestock and agricultural economy. It contains about 12 percent of the State's population. The potential industrial development of this area, however, is of great magnitude. Locked in the shale deposits of the Colorado River Basin are oil reserves estimated to be several times greater than the petroleum reserves of the entire world. During the past 15 years about $50 million has been spent in shale oil development. Economical mining and retorting processes have now been developed, and careful study indicates commercial shale oil production may be underway by 1965. At least 250,000 acre-feet of water annually must be reserved for this potential industry and allied municipal growth.

Colorado's greatest activity in water resources development through 1980 and thereafter will occur in the Colorado River Basin. Currently two reclamation projects are under construction in western Colorado and money has been appropriated for a third. The keystone project, the Curecanti on the Gunnison River, is awaiting a congressional appropriation for construction.

The total expenditures for water resource development in the Colorado River Basin in Colorado through 1980, are estimated at $651,044,000, of which $633,109,000 is classified as Federal investment and $17,935,000 as non-Federal.

State summary

This statement gives only a very brief picture of the river basins of this State. Material presented at the Denver hearing of the committee[1] covers in greater detail the water resource problems of each of the river basins. As can be readily perceived, there has been in the past and will continue to be in the future great competition among various users in various sections of the State, over the remaining water resources. We are already faced with the necessity for better conservation practices. Such practices can be developed only after patient and exhaustive basic research.

The total expenditure for water resource development in this State projected through 1980 is estimated at $1,300,535,100. Of this amount $1,041,485,000 is classified as a Federal expenditure and $259,050,100 as non-Federal. This total expenditure is summarized by purpose and river basin in the attached table III. These figures do not include any expenditures for the development of ground water.

Merely for the purposes of comparison, we have shown on the attached table IV, Federal expenditures for completed water projects in Colorado during the past 55 years. This table does not include expenditures by the Soil Conservation Service.

From this thumbnail sketch of the surface water resources of the State of Colorado, we now refer to more specific topics.

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[1] Hearings on Water Resources, Senate Select Committee on National Water Resources, pt. 11, Denver, Colo., Nov. 20, 1959.

TABLE III.—*Estimated expenditures for water resource development in Colorado, 1954–80*

	Irrigation	Municipal and industrial	Flood control	Fish and wildlife and recreation	Hydroelectric power	Total
Platte River Basin:						
Federal	$71,487,000	$9,200,000	$22,931,000	$609,000	$77,500,000	$181,727,000
Non-Federal	513,000	[1] 184,454,000	4,935,000	223,000	42,000,000	232,125,000
Total	72,000,000	193,654,000	27,866,000	832,000	119,500,000	413,852,000
Arkansas River Basin:						
Federal	82,336,000	34,200,000	29,327,000	1,906,000	46,500,000	194,269,000
Non-Federal	1,345,000	(1)	7,068,000			8,413,000
Total	83,681,000	34,200,000	36,395,000	1,906,000	46,500,000	202,682,000
Rio Grande River Basin:						
Federal	19,580,000		12,300,000	500,000		32,380,000
Non-Federal	286,100		150,000	141,000		577,100
Total	19,866,100		12,450,000	641,000		32,957,100
Colorado River Basin:						
Federal	465,493,000	2,500,000	1,272,000	5,702,000	158,142,000	633,109,000
Non-Federal	2,868,000	10,036,000	2,758,000	2,273,000		17,935,000
Total	468,361,000	12,536,000	4,030,000	7,975,000	158,142,000	651,044,000
State total recapitulation:						
Federal	638,896,000	45,900,000	65,830,000	8,717,000	282,142,000	1,041,485,000
Non-Federal	5,012,100	194,490,000	14,911,000	2,637,000	42,000,000	259,050,100
Total	643,908,100	240,390,000	80,741,000	11,354,000	324,142,000	1,300,535,100

[1] $33,000,000 in this category shown in the Platte Basin is actually a joint enterprise between the Platte and Arkansas River Basins

TABLE IV.—*Completed Federal projects in Colorado*

BUREAU OF RECLAMATION[1]

Project	Date	Cost
Uncompahgre	1904	$11,922,797
Grand Valley	1912	8,688,602
Pine River	1938	3,444,294
Fruitgrowers	1938	200,309
Colorado-Big Thompson	1938	159,385,440
Mancos	1941	3,949,840
Platoro	1949	3,837,415
Total, Bureau of Reclamation		191,428,697

CORPS OF ENGINEERS

Project	Date	Cost
John Martin	1940	$15,070,000
Cherry Creek	1946	14,600,000
Templeton Gap	1948	888,900
Creede Willow Creek	1949	162,089
Pueblo	1952	217,500
Aurora	1952	150,000
Total, Corps of Engineers		31,088,489
Grand total, both agencies		222,517,186

[1] Bonney Reservoir constructed in eastern Colorado not shown since benefits are largely in Kansas.

Water uses

Water uses in Colorado can be classified in three general categories, to-wit: agricultural, municipal and industrial, and recreational. Recreational uses, until recent years, have largely been incident to the other uses. However, recreation associated with Colorado's streams and lakes has now become a major industry and must be regarded as an integral part of all water resource development.

Since water supplies are limited, tremendous competition has developed among the various uses. At the present time a significant portion of municipal and industrial water supplies were formerly used for irrigation. The basic economy of Colorado has changed successively from mining to agriculture, and from agriculture to industry. Demands for all uses will continue to increase. Simple economics at this time indicate that municipal and industrial uses are in the most competitive position.

It has not been possible to adopt any fixed policy in this State with reference to the various competing uses. Increased attention, however, is being given to the planning of future water supplies for municipal and industrial purposes. At the same time we must bear in mind that in future years our present agricultural production will not be sufficient to feed and clothe the rapidly multiplying human population. Recreational uses, regardless of their desirability, will be primarily incidental to other uses.

Water quality

Until recent years water quality had not been a general problem to the State of Colorado. Today, however, the widespread use of detergents, municipal and industrial wastes, together with the dimunition of streamflow, are creating serious water quality problems. These problems become aggravated with the passage of each year. The basic change from an agricultural to an industrial economy is now being reflected in both surface and ground water supplies.

During the past 2 years the residents of northwestern New Mexico have become alarmed over radioactive wastes discharged into the San Juan River from milling activities in Colorado. Remedial action is now being undertaken by the milling companies to eliminate the contamination, but it should never have occurred in the first instance. In recent weeks all of Colorado has been aroused to learn that toxic wastes from the U.S. arsenal near Denver have seriously contaminated the ground water supplies of that area. The tragedy of this contamination lies in the fact that even assuming that that contaminating source has been, or will be, removed, there is no known method of purifying the contaminated ground water supply. It may be that the ground water aquifer in that area will be contaminated for a period of from 5 to 15 years. This type of contamination again is inexcusable.

To date, water quality control and inspection has been a neglected stepchild to water resource development and planning. At the present time only the State and Federal health agencies have made active attempts to prevent the contamination of water supplies. Those agencies have had little or no help from other agencies of the State and Federal Governments in preventing the contamination before it occurs. We have long neglected this important water quality problem in our State planning and have made little use of the services offered by the Water Quality Branch of the U.S. Geological Survey. We are sure that the people of this State, in the near future, will demand that all agencies of the State involved with water resources give the highest priority to water quality inspection and control. The Federal Government can be of great assistance in this field, but like our own State agencies, the agencies of the Federal Government are poorly coordinated in achieving the maximum prevention and control of water pollution.

Water conservation and basic research

As already pointed out, the natural surface water supplies of three of our major river basins in Colorado are already largely exhausted. However, the ability of the human race to propagate has not become exhausted. Consequently the same water supply which may seem insufficient for 100,000 people today, may have to suffice for a million people in the future. Better utilization, salvage, and reuse of water are the only ultimate answers.

In the San Luis Valley, in cooperation with the Bureau of Reclamation, we have under study various methods of salvaging water now going to waste. The cost of this program is being shared equally between the State and the Federal Government. Similar projects are in the planning stage for the Arkansas and South Platte River Valleys.

Basic research in water utilization and production has long been one of the most neglected fields of scientific endeavor. Research activities of both State and Federal agencies have had no real impetus nor ultimate goal. Statements were presented at the Denver hearings of the committee [3] by Dr. Morgan of Colorado State University and by Dr. Roberts of the University of Colorado on the subject of research. We have on the technical staff of our water conservation board, persons who are experts in the field of water resource development. These people are of the unanimous opinion that they are seriously handicapped in the performance of their work because of the lack of basic research on water problems.

Federal-State relations

The Federal Government has played a vital part in the development of the water resources of the State of Colorado. Its agencies have been indispensable to the welfare of this State and to every other State of this Union and will continue to be so. The particular agencies involved in the development of our water resources are the Bureau of Reclamation, U.S. Geological Survey, the Corps of Engineers, and the Soil Conservation Service.

One of the oldest reclamation projects in the United States was begun in Colorado in 1904. Since that time reclamation development has been rather slow in Colorado, but with the passage of the Colorado River Storage Project Act in 1956, reclamation activity in Colorado has reached a new height of activity.

Since the construction of the Colorado-Big Thompson project, our Weld County, north of Denver, has become one of the leading counties in the Nation in the value of agricultural production. It is no mere coincidence that the four most populous counties in western Colorado are also areas of reclamation development. Our relationship with the Bureau of Reclamation has been, on the whole, most cordial.

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[3] Ibid.

For several years past our Colorado General Assembly has been appropriating the sum of $100,000 annually to be expended under cooperative agreements with the Bureau of Reclamation. In addition to this expenditure, the engineering and legal staff of our water conservation board often work jointly with Bureau personnel on various studies and investigations. We would very much like to cooperate with the Bureau of Reclamation in basic research activities, but funds appropriated to that organization for such purposes have been negligible.

An agency which does not receive its proportionate share of credit in the development of this Nation's water resources is the U.S. Geological Survey. This important agency has been responsible for recording and disseminating the water supply data upon which all of our projects are based. The State of Colorado is now expending over $30,000 annually in a cooperative program with the U.S. Geological Survey in obtaining and recording basic streamflow data. The general assembly is now appropriating the sum of $75,000 annually for a cooperative survey of our ground water resources. In the future we expect to enter into cooperative agreements with the Water Quality Branch of that agency.

Two major projects have been constructed in the State of Colorado by the Corps of Engineers, and the Trinidad project on the Purgatoire River was recently authorized by the Congress. The corps plays an important part in determining flood control benefits of projects constructed by other Federal agencies. There still remains considerable flood control work to be done in Colorado, although a major portion of the problem will be solved by the flood control capacity of Bureau of Reclamation projects. The flood problem in the Denver metropolitan area has become aggravated in the past few years as a result of poorly supervised subdivision planning and construction.

There is often a tendency to lose sight of the work of the Soil Conservation Service because of the magnitude of projects constructed by other Federal agencies. Nevertheless the work of this agency is becoming of increasing importance to the State of Colorado. Several important projects planned by the Soil Conservation Service are now under construction and nearing completion on our eastern plains. The accumulative effect of these small projects constructed at strategic locations, is often more beneficial than a single project of great magnitude. The Colorado office of that agency is understaffed and is being supplemented by a planning party from the staff of our State Water Conservation Board.

Soil and moisture conditions are a primary investigative function of the Soil Conservation Service. The proposed high plains soil and moisture laboratory is of tremendous interest to the Colorado Association of Soil Conservation Districts. Mr. Clarence A. Foster of Colorado Springs, State president of this association, has requested that we convey the association's endorsement of such a laboratory. The establishment of this laboratory is also strongly urged by our board, since it would accomplish vitally needed basic research on soil and moisture conditions.

Ground water resources

This statement has heretofore been primarily limited to the surface water resources of this State. However, we do not wish to convey the impression that we are entirely dependent upon surface water supplies. In the Rio Grande River drainage in Colorado, extensive use has long been made of ground water resources. Both the Arkansas and Platte River valleys contain important ground water aquifers. The use of these resources is rapidly increasing to the point that there is considerable suspicion that it is interfering with surface water supplies. Experience has already shown us that ground water supplies can be rapidly depleted. We have been reluctant, to date, to grapple with the problem. At the present time we have no specific law which regulates the use of ground water. Ground water, because of its elusive nature, has not been readily susceptible to workable controls.

As has already been mentioned, we are cooperating with the U.S. Geological Survey to the extent of $75,000 per year, to determine the extent and character of our ground water resources. We anticipate that this Statewide survey will be completed within the next 10 years. This survey is only a partial solution to the ground water problem. Much work must be done to determine the relationship between ground and surface waters.

Conclusion

We are sure that this committee has already come to the conclusion that there is a remarkable similarity among the water problems of the various States. It is a rare instance in which there is no interstate competition over a common source of water supply. Pollution and flood control problems have no respect for State boundaries. The U.S. Supreme Court has repeatedly held that no State has exclusive jurisdiction over waters originating within State boundaries. We are in accord with this principle as long as it is confined to factual situations involving interstate compacts and relations. What we are observing here is that water problems are of national scope, and therefore a legitimate and necessary field of activity for the Federal Government.

Throughout this presentation we have referred to the exhaustion of water supplies in the various basins of this State. We did not mean to infer that such water supplies have been exhausted to the extent of maximum possible utilization. The term was used to denote exhaustion under our present methods of use. Probably no natural resource has been, or is being, subjected to such extravagant waste as our water resources. Fortunately, man's activities do not destroy the basic characteristics of water. It is obvious, however, that the only ultimate answer to the water problem lies in the maximum use and reuse of the waters that are made available to us by nature. Basic research to promote this maximum use has been feeble and almost completely uncoordinated. Only by entering actively into this field of endeavor can the Federal and State Governments discharge their responsibilities to the people of this country.

CONNECTICUT

State of Connecticut,
Executive Chambers,
Hartford, September 23, 1959.

Hon. Robert S. Kerr,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: In reply to your request for a statement concerning Connecticut's water problems, I enclose a report together with several exhibits[1] which supplement it.

The report was prepared and the exhibits assembled by Director William S. Wise of the Connecticut Water Resources Commission.

Sincerely,

Abraham Ribicoff, *Governor.*

Memorandum Concerning Program of Senate Select Committee on National Water Resources

The committee is composed of 17 Senators—only 2 of which represent States east of the Mississippi River, Michigan and Pennsylvania. It is unfortunate that the committee is composed of such an overwhelming majority of Senators representing western views, regions, and interests. Eastern water laws, policies, and problems are totally different from those in the West and this difference should be fully recognized and thoroughly considered in any report dealing with the vital problem of national water resources. It is assumed of course that the data collection and technical portions of the report will be assembled under a uniform procedure and it is hoped that the recommendations for needed projects and legislation will recognize the diverse needs and problems existing between the various regions of the country.

Existing conditions in Connecticut.—There are a number of areas in the State where the water needs exceed the supplies, particularly for municipal and industrial purposes. However, in the State as a whole, the conditions are not now as critical as they are in some of the western and southwestern regions. Nevertheless, it is generally conceded that the water needs here are expanding rapidly and the conditions in many areas will become critical unless comprehensive programs are advanced in the near future. The needs are increasing in all important water resource fields: municipal supplies, industrial supplies, recreational activities, and agricultural uses.

Program and accomplishments in Connecticut.—The most comprehensive study, ever undertaken in the country, was carried out on the natural resources in New England between 1950 and 1955 by the New England New York Interagency Committee (NENYIAC). The report covers 43 volumes, and while it has not been brought up to date, it contains much of the information to be sought under the first phase of the "General Outline of Proposed Procedures" under which the select committee will work.

In 1956 the New England Governors' Conference set up the Northeastern Resources Committee to continue and implement the work and recommendations of the NENYIAC report. A copy of the charter is enclosed as exhibit 1. A "Charter for a Northeastern Resources Committee" compact based on this charter has been passed by the legislatures of Connecticut and Rhode Island and considered in the other New England States. There is also much interest in this committee and compact among other States in the Northeast. The select committee should work through Northeastern Resources Committee in its studies.

In 1955 the legislature authorized a study committee to report to the 1957 session of the legislature on the "Water Resources of Connecticut." A copy of this report is attached as exhibit 2.

In 1951 a cooperative project was initiated to develop a flood flow formula for Connecticut. This was undertaken by the: State Water Commission; State Board for Supervision of Dams; State Highway Department; and the U.S. Geological Survey with the studies made by the latter agency. A copy of this study "A Flood-Flow Formula for Connecticut" is attached as exhibit 3 (Geological Survey Circular 365).

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[1] Not reprinted here.

In 1947 the legislature authorized a committee to advise on the Connecticut beach erosion problem. A copy of this report is attached as exhibit 4. The comprehensive study of the entire shoreline has been made by the Beach Erosion Board—New England Division, U.S. Army Engineers with reports and recommendations on each of the 11 areas along the shore. The State water resources commission has been carrying out a construction program, authorized by the legislature, over the past 4 years at a cost of $4 million. The program is continuing with increasing public demand.

Connecticut has been carrying on a cooperative program with the U.S. Geological Survey for 30 years on various phases of water resources. The program includes three types of studies: (1) Surface water-stream gaging program, (2) ground water studies, (3) quality of water studies. A large amount of fundamental data has been collected under this program and requests without much success have continuously been made to the legislature to expand this much needed program to meet the growing public demands. Some of the results of the ground water studies are contained in the following copies of reports attached: Exhibit 5, "Ground Water in North Central Connecticut"; exhibit 6, "Geologic Factors Affecting the Yield of Rock Wells in Southern New England;" exhibit 7, "Ground Water Problems in New York and New England." In addition the following reports are in preparation: "Chemical Quality of Water Resources in the Housatonic, Connecticut and Thames River Basins"; "Ground Water Resources of Farmington-Granby area, Connecticut"; "Water Resources of the Hartford-New Britain Area, Connecticut"; "Water Resources of the Waterbury-Bristol Area"; "Flood-Flow Formula for the New England States."

Connecticut has been carrying on a cooperative program with the U.S. Geological Survey as the geological mapping program of the entire State. Information from this work is invaluable for carrying out water resources investigations and inventories. It is hoped that this program can be expanded through increased appropriations by the legislature and Congress.

The need in Connecticut is great for a complete inventory of the State's surface and ground waters. The 1959 session of the legislature authorized the water resources commission to carry out a 10-year program. However, no funds for the work were appropriated. A copy of this act is attached as exhibit 8, "An Act Concerning Inventory Development and Conservation of Water Resources." It is hoped that funds for carrying out this work will be made available by the next session of the legislature.

In 1925, Connecticut set up a comprehensive water pollution control program by establishing the State water commission. In 1939, the legislature established the State flood control and water policy commission and the State board for supervision of dams. In 1957, these agencies were merged into one agency, the water resources commission. Exhibit 9 contains the various statutes which are administered by this commission. In 1959, the legislature merged certain functions of various agencies and set up a council to review any conflicts of activities in the field of natural resources. A copy of this act is attached as exhibit 10, "An Act Creating a Department of Agriculture Conservation and Natural Resources," This act seeks to coordinate the activities, largely in the field of water resources of the water resources commission; agriculture department; park and forest commission; fisheries and game commission; shellfish commission; and development commission.

The 1959 legislature established a weather control board to make studies and conduct research in this field. Exhibit 11—An Act Establishing a Weather Control Board is attached.

Connecticut has an outstanding record of results in its water pollution control program. In 1953 the water commission and department of health issued a pamphlet indicating what has been done and what remained to be done. A copy of this pamphlet (not up to date) is attached. Exhibit 12 "Connecticut's Waters—Wealth or Waste."

Since 1955 Connecticut has pioneered in the field of flood control as a State program. Many problems in the State are in urgent need of solution but fall outside the realm of the Federal Government through the Army Engineers. Connecticut, therefore, set up a program of coordination and cooperation of many projects large and small with the Army Engineers, under which the State spends substantial funds for corrective measures. The State's program for regulating stream enroachments has received nationwide attention and consideration. Exhibit 9 contains the duties of the water resources commission in the fields of flood control and the regulation of stream encroachments. In the interests of programing the preservation of wildlife habitat not inconsistent with the needed developments along our shore and navigable waters the water resources commission is authorized to regulate the dredging of sand and gravel from tidal waters.

Through the State department of agriculture and the soil conservation advisory board, Connecticut cooperates with Federal agencies in carrying out the provisions of Public Law 566 seeking to provide measures of flood control and soil erosion on small watersheds in the State. A number of projects are in various stages of study, planning or construction.

Summary of activities and programs.—The previous listing of activities, programs, investigations and policies indicates:

(1) Much information is available concerning the problems involving water resources in Connecticut, and in New England, but a great deal more is needed to plan adequately for meeting the rapidly growing future demands.

(2) The NENYIAC report of 1955 and the report on water resources of Connecticut contain a wealth of basic data on Connecticut and New England water resource problems and should serve as the principal source of information, after they are brought up to date.

(3) The northeastern resources committee, operating under a compact, is an appropriate agency through which any other agencies could and should work in investigating and programing the development of the water resources of this region.

(4) Connecticut has pioneered in many phases of water resources management and development and has on its statute books many basic laws for promoting a sound water policy to meet the State's needs. The statutes obviously need to be amended and supplemented to fit into a comprehensive program.

(5) Connecticut is well equipped with agencies, both State and private, and with an excellent background of experience to initiate, and cooperate with Federal and other agencies, in investigating the State's future needs in water resources and in formulating a sound and adequate program to meet the anticipated needs.

Who should do what.—It is obvious that Connecticut has grown and prospered under a system of laws and policies which may differ in various degrees from those of other States and regions. It is also obvious that the future demands for water in the State cannot be met without changes in these laws and policies. However, because the State is blessed with certain natural conditions and potential assets it is almost certain that the future needs can be met without the extreme measures that will be necessary in other States and regions.

It is also obvious that a sound program for conserving and developing the Nation's water resources cannot be formulated or administered without a sound national policy. This policy must recognize the differences in customs, policies, and needs throughout the various States and regions. Therefore any Federal policies or statutes should permit or authorize the various States or regions to exercise the initiative, the planning prerogatives and administrative responsibilities consistent with the local needs and conditions.

DELAWARE

STATE OF DELAWARE,
EXECUTIVE DEPARTMENT,
Dover, September 30, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: In accordance with your request of June 23, 1959, we are submitting herewith copies of a summary report on Delaware's water resources and associated problems.

The State of Delaware has recently completed a rather voluminous "Intrastate Water Resources Survey Report." This water resources survey is to become appendix O of the "Comprehensive Water Resources Survey of the Delaware River Basin," now being prepared by the Corps of Engineers, Philadelphia District. At present, the first draft printing of appendix O is being made by the Corps of Engineers and should be completed in approximately 30 days. The attached summary contains excerpts and condensations from our "Intrastate Water Resources Survey Report."

The projected water needs are compiled in a comprehensive manner, on a multiple-use basis, to the years 2010 and 2060. We have, in accordance with your request, interpolated our estimates to include the year 1980. The bases for the projections are taken from extensive information accumulated by the various departments and/or interests of the State of Delaware.

The attached résumé emphasizes the extensiveness of water resources data and evaluations. Considerably more detail is needed for proper coverage than can be readily presented in a brief summary. Therefore, the recently completed "Intrastate Water Resources Survey Report" is pertinent and will be made a part of the above summation as soon as it is received from the printers.

This State survey contains 29 chapters, including the inventories of consumptive and nonconsumptive uses of water, recreation needs, fish and wildlife, agriculture, and many other groups. In addition, there is a chapter on desalinization or a review of factors affecting saline water conversion.

If you desire further information, we shall make every effort to comply.

Respectfully yours,

J. CALEB BOGGS, *Governor.*

OCTOBER 30, 1959.

STATE OF DELAWARE PRESENT WATER USE AND PROJECTED NEEDS BY 1980

I. INTRODUCTION

The State of Delaware has changed in many ways during the past decade and indications are that even greater changes will take place which will affect every citizen in the future. The data reported underline the fact that Delaware will be deficient in available water supply to meet its needs long before the year 2010, and even before 1980 in our New Castle County, which is the most populated in the State. The outlook for the future development of Delaware is not encouraging unless the residents, by their own efforts, utilize to the best advantage the available water, but in any case water must be obtained from beyond the boundaries of the State. Unless water resources can be made secure, the major problem in the State will not be highways, nor education, nor agriculture, nor forests, nor industry, nor any other phase of our day-to-day activities, but the availability of water.

The State of Delaware has recently completed and submitted for printing an extensive report entitled, "State of Delaware Intrastate Water Resources Survey." This compilation has been submitted as the State of Delaware's appendix to the Corps of Engineers' "Report on the Comprehensive Survey of Water Resources of the

Delaware River Basin." The Delaware report comes as a result of almost 3 years of effort by the State coordinators, State agencies, county agencies, and other interested organizations, public and private, who participated.

The following summary contains excerpts and condensations of data presented in the "Delaware Intrastate Water Resources Survey Report." The complete report summarizes the present water use data and projected needs for the years 2010 and 2060. In order to comply with the Senate Select Committee on National Water Resources request of June 23, 1959, interpolated projections for the year 1980 are made a part of the data reported herein.

The projected water needs phase for the State of Delaware was contributed primarily by the following interests:

1. Department of Agriculture, University of Delaware, with respect to irrigation.
2. Department of Civil Engineering, University of Delaware, for surface water evaluation.
3. Delaware Geological Survey, University of Delaware, for its ground-water evaluation.
4. State board of health, for its municipal water tabulations.
5. The State highway department, and many other participants for its projected land-use estimates.
6. The water pollution commission, for its ground-water quality evaluation and industrial water inventory.
7. State coordinators and the statistician of the State board of health, for population, etc., projections for each county.
8. Various major industrial groups for their invaluable assistance with respect to projected industrial needs.

An estimate of land availability had to be resolved before irrigation use projections could be made. These estimates are presented in separate tables below. The rate of irrigation water use is approximately 15 percent less than that projected by the U.S. Department of Agriculture. However, until more finite evaluations can be made, this conservative figure has been used.

Water use with respect to irrigation is projected on a 60-day maximum basis since this is the potential period during which water will be supplied. If expressed as a 30-day maximum, the figures would be greater.

Present domestic consumption (30-day maximum) in Delaware averages 100 gallons per capita per day. Until further study a conservative 125 gallons per capita per day was used for the years 1980 and 2010, and 150 gallons per capita per day for the year 2060. Present thinking and past records clearly show that domestic water requirements have increased at a much more rapid rate.

Due to time limitations, means of obtaining projected needs with respect to major industrial water users was given detailed consideration with regard to projected needs. A conservative average increase of 5 percent per year was applied to the remaining industries.

The coordinators have endeavored to project the needs for the State of Delaware to the year 2060 because they are cognizant that the periods beyond 1980 are quite pertinent to the overall problem.

II. POPULATION, PROJECTIONS BY COUNTY

Projected populations is summarized in table I. These projections were based on State records and extrapolated through the year 1965, and from 1956 on, the growth rates were determined from the report of the Office of Business Economics submitted as an appendix to the Corps of Engineers report. Since the Office of Business Economics report is tabulated according to various subsections within the Delaware River Basin, it was necessary to extrapolate these projections for the State of Delaware so that they could apply to this State. Certain minor modifications were made to validate projections on the county level.

TABLE I.—*Population by counties* [1]

[In thousands]

	[illegible]al, [illegible]56	Projected			
		1965	1980	2010	2060
New Castle	261.9	398.1	531.2	912.4	2,248.6
Kent	61.0	122.2	169.0	274.5	616.3
Sussex	73.1	110.7	156.5	239.5	487.2
Total	396.0	631.0	856.7	1,426.4	3,352.1

[1] Source of information, "State of Delaware, Intrastate Water Resources Survey, ch. X, Growth and Development Projections," p. 10-8.

III. FACTORS AFFECTING PROJECTED WATER NEEDS

Most surface water sources, due to hilly terrain, lie in the extreme northern portion of the State of Delaware and, in contrast, our major ground-water sources are located in the flat terrain of central and southern Delaware. The following analyses are pertinent to surface and ground-water availability:

A. Surface sources

Earlier detailed analyses of dam sites considered for the Brandywine, White Clay, and Christina watersheds represented an extensive degree of development. At the pool elevation selected, a combined (Brandywine, Christina, and White Clay) minimum range of development would provide a safe yield for a 25-year recurrence interval of 275 million gallons per day. Similarly, the combined maximum range of development would provide a safe yield for a 25-year recurrence interval of 402 million gallons per day, which is considered presently as uneconomical. However, it seems appropriate to consider the maximum potential because, if no other source is available, the pool may become economical.

Several considerations must be resolved before any estimate can be made of what portions of these sources can be judged safe yield for the State of Delaware. These considerations involve one or more of the following:

1. Approximately 90 percent of the maximum Brandywine pool would be in Pennsylvania. Diversions for out-of-basin use are highly probable and, consequently, the safe yield undoubtedly would be reduced.
2. Irrigation trends and experience, if practiced to any moderate extent, indicate that this safe yield would be materially affected.
3. The proposed maximum Brandywine Dam site in Pennsylvania involves approximately 85 percent control of its waters. This should be compared to the very extensive water development of Gun Powder Creek by the city of Baltimore, constituting 56 percent control. It is possible that such extensive development of the Brandywine may not be feasible.

B. Ground water

Ground water safe yield in the State of Delaware has been estimated at 418 million gallons per day. Of this total, 400 million gallons per day, or 95 percent, is in the Pleistocene sands located in the central (southern half of Kent County) and southern (Sussex County) parts of the State. Some considerations pertinent to ground-water availability estimates are:

1. Ability of ground water recharges are complex and not too well known. Recharge could be greater than the estimates now used; however, the reverse can equally be true.
2. There is evidence of saline intrusion in the downstate counties as high chlorides have been found in untapped aquifers.
3. Ground-water quality dictates treatment, in certain areas, before universal use can be made. Extensive analysis indicates that waters from the Pleistocene sands are invariably very acid (low pH) and extremely high in iron.

IV. PRESENT WATER USES IN THE STATE OF DELAWARE

In order to provide a basis for projected water use, there must be adequate data on present use. Present-use tabulations were compiled from: (1) a complete inventory of industrial water use, (2) a complete inventory of irrigation, and (3) a complete inventory of municipal water use.

A 1957 summary of water use in the State of Delaware is presented in five separate tables (addendum, tables 1–5). Each of these tables is divided into three sections: maximum use, average, and 30-day maximum. These presentations were prepared in this manner in order to fulfill the needs associated with the variability of water demand. The maximum use data provide an indication of the instantaneous demand and show the comparative magnitude for peak period design. The average tabulations indicate total use or storage requirements over an extended period of time. The 30-day maximum, however, is the most valid presentation of present needs and the basis for future projections. The latter essentially pertains to periods of dry weather conditions when water is in greater demand.

For expedience, collection of complete maximum data, specifically with respect to surface water, was not made and therefore these tabulations are conservative. The maximum, as expressed under public surface and ground-water installations, is the same as the 30-day maximum. The instantaneous maximum would be greater. In addition, the 30-day maximum was recorded as the instantaneous maximum for most of the steam generation uses.

Whenever a municipal system supplied both the domestic and industrial needs, a segregation was made so that the tabulations recorded would show a true domestic use and a true industrial use. The water provided for domestic and/or industrial uses is accurately recorded in the larger municipal water systems. Where industrial needs are supplied from a municipal system in the smaller communities, estimates were made and on the basis that 70 gallons per capita per day is the normal domestic need and the balance was assumed as industrial water. However, this latter segregation constitutes only a very small percentage of the total, and the estimates applied to industry or domestic use do not materially affect the overall pattern.

The 30-day maximum tabulations reflect water use during the dry weather periods. A significant percentage of this 30-day maximum appears as irrigation water. The irrigation water use for 1957 has been tabulated to show the instantaneous maximum in any 1 day, the average application during a 30-day period, and also the average use over a period of 365 days.

The industrial water inventory (table 1) presents the total water take by industry for maximum demand, the average, and the 30-day maximum periods. No public utilities are supplied by surface water sources in Kent and Sussex Counties. The terrain is so flat in these lower counties and the tributaries are so small that a safe and reliable surface yield of water for municipal needs is not practical. It is possible, however, that the Nanticoke River drainage basin could be used, after treatment, as a surface water source. However, none is being taken from this stream for domestic use at the present time. Ground-water resources in New Castle County are small compared to those of the lower counties. The comparatively high figures for New Castle County ground water taken from private sources consist primarily of water from the Tidewater refinery wells. The surface water totals for industry from public sources are derived primarily from the Wilmington Water Department and the Delaware Water Co., both in New Castle County. The surface water totals from private sources are primarily steam generation and industrial cooling waters. In New Castle County the major users are the Tidewater refinery and the Delaware Power & Light Co. In Sussex County the relatively high surface water withdrawals are for steam generation and industrial cooling at the municipalities of Millsboro, Laurel, Seaford, and the Du Pont nylon plant. The municipal water inventory (table 2) shows a greater supply being delivered to industry than to the public from municipal surface sources.

The total ground-water inventory shown in table 3 is a composite-type table which includes the tabulations presented in tables 1 and 2. The industrial and public tabulations show the total of both the private and the public ground-water sources supplying water to industry. The section designated as public represents all waters supplied for domestic needs from ground-water sources. Miscellaneous uses include, as pointed out previously, the waters supplied to the military installations and State institutions. These include such installations as the Dover Air Force Base, the New Castle County Airport, Governor Bacon Health Center, and other State institutions.

The surface-water inventory, as shown in table 4, is also a composite-type table including totals from tables 1 and 2. Several significant facts can be brought out from these tabulations. The 30-day maximum summation of the industrial uses total 943 million gallons per day. A major portion of this total is steam generation use and industrial cooling water. Attention is directed to the irrigation listings. Quite significant is the fact that the instantaneous maximum in any one day of irrigation use during 1957 constituted one-fourth of all water use in the State of Delaware, including steam generation and industrial cooling. This figure is most significant, in that it shows the relationship of irrigation needs as compared to other water usages. Even the 30-day maximum of 103 million gallons per day becomes very much a major use. The 30-day maximum irrigation water use is 400 percent greater than all the water used for domestic purposes in the State of Delaware.

The total summary water use for the State of Delaware during 1957 is shown in table 5 and combines all the tabulations as presented in the previous tables, but in a more concise manner. The average total for all water uses in the State of Delaware is 602,449 gallons per minute or approximately 867 million gallons per day. This may be compared to the more significant 30-day maximum of 807,282 gallons per minute or 1,162 million gallons per day. The greatest water use is from surface sources (table 5). Of the 30-day maximum use 75.6 percent is industrial cooling and steam generation.

V. PROJECTED LAND USE

In order to provide a means of estimating the irrigation requirements in the years 1980, 2010, and 2060, considerable detail of future land use had to be resolved. The State soil conservation commission must be given credit for a very realistic approach in providing information with respect to future irrigation needs. This agency indicated that they feel they could not compete on a priority basis with land use for incorporated areas, housing and subdivisions, industrial sites, Government land, and highways. They further indicated that they could compete on a priority basis with all other land uses. Consequently, it had been requested of the coordinating committee to make a detailed survey of the State's lands and determine the number of square miles that would be used under the present growth projections of the five prior uses indicated above. This detailed analysis was performed by the State coordinators, and the results are presented in addendum table 6. A summary of these various land requirements for the years 1980, 2010, and 2060 is presented in table 7. It may be noted in table 7 that the minimum available land in Kent and Sussex Counties, constituting a total of 1,121 square miles, was originally considered available for farm use. However, of this total 621,000 acres, or 970 square miles, according to the State soil conservation service, is irrigable. Assuming all this land to be available for farming and irrigation, the total water needs in the year 2060, projected on the basis of an application of 7 inches per acre, would amount to 1,735 million gallons per day (60 irrigating days). However, for the year 2010, the Department of Agriculture indicated that only 35 percent of this total requirement, or 607 million gallons per day, would be needed. The needs for 1980 were reduced proportionally.

VI. PROJECTED TOTAL DOMESTIC USE

In table 8 are listed, by county, the present use and projected needs for domestic water in the State of Delaware. It may be noted that this projection is based on a 30-day maximum which results in an average 2.2 times increase by 1980 in the domestic need to 102.39 million gallons per day.

VII. PROJECTED TOTAL INDUSTRIAL USE

A summary to the present use and projected needs for industrial requirements in the State of Delaware is presented in addendum table 9. The values in this table include cooling water, which is taken either from fresh water streams or brackish sources. The comparatively large increase for the years 1980, 2010, and 2060 is attributable to large industrial cooling requirements, namely, those of petroleum refineries and steam generation plants. Wherever feasible, the separation of the ground and surface sources was noted in the tabulation.

VIII. PROJECTED TOTAL WATER USE

A total summary of industrial, municipal, and irrigation needs projected for the years 2010 and 2060 is presented in table 10. It should again be noted that the industrial projections include cooling water needs, and the irrigation requirements are based on the 60-day maximum rates. This is a composite of tables 7, 8, and 9.

IX. PROJECTED TOTAL WATER USE EXCLUDING INDUSTRIAL COOLING

A more significant presentation is the summary water use and projected needs, excluding cooling and steam generation, for the State of Delaware as shown in table II. This summary is more significant since it provides the actual fresh water supply needs for the State of Delaware. If we were to assume that the entire minimum development of 270 million gallons per day, referred to previously, could be assured for the State of

Delaware, we would have less than half of the water required for New Castle County alone in the year 2010, and considerably less for the year 2060. The ground-water sources in New Castle County are comparatively minor.

TABLE II.—*State of Delaware summary, water use and projected needs excluding industrial cooling and steam generation* [1] [2] *(30-day maximum)*

[Million gallons per day]

	1958	1980	2110	2060
New Castle:				
Industrial	71.0	176.30	319.9	1,262
Municipal	32.8	67.13	114	337.5
Irrigation [3]	24.65	70.58	133.2	0
Total	128.45	314	567	1,600
Kent:				
Industrial	23.35	48.10	81.85	286.35
Municipal	7.63	18.91	34.30	92.40
Irrigation [3]	53.80	110.15	187.0	622
Total	84.78	177	303	1,001
Sussex:				
Industrial	31.45	65.70	112.4	436.3
Municipal	6.34	16.32	29.95	73
Irrigation [3]	25.35	136.05	287	1,113
Total	63.14	218	429	1,622

[1] Reference: "State of Delaware Intrastate Water Resources Survey," August 1959.

[2] Taken from surface streams.

[3] 60-day maximum.

TABLE 1.—*Industrial water inventory, 1957, State of Delaware* [1]

[Gallons per minute]

County	Number of industries	Ground water		Surface water	
		Public	Private	Public	Private
		Maximum			
New Castle	351	530	16,875	18,800	648,156
Kent	146	1,422	18,243	None	6,570
Sussex	180	1,798	22,981	None	161,630
Total	677	3,750	58,099	18,800	816,356
		Average			
New Castle	351	467	8,450	13,030	423,364
Kent	146	988	10,538	None	4,250
Sussex	180	904	16,198	None	95,315
Total	677	2,359	35,186	13,030	522,929
		30-day maximum			
New Castle	351	530	12,597	18,800	503,281
Kent	146	1,422	14,702	None	5,070
Sussex	180	1,798	19,172	None	125,415
Total	677	3,750	46,471	18,800	633,766

[1] Reference: "State of Delaware, Intrastate Water Resources Survey," August 1959.

TABLE 2.—*Municipal water inventory, 1957, State of Delaware* [1]

[Gallons per minute]

County	Rural [2]	Ground water		Surface water	
		Domestic	Industrial	Domestic	Industrial
		Maximum			
New Castle	540	5,230	530	15,800	18,800
Kent	1,370	1,460	1,422	None	None
Sussex	1,795	2,070	1,798	None	None
Total	3,705	8,760	3,750	15,800	18,800
		Average			
New Castle	540	3,230	467	10,300	13,680
Kent	1,370	952	988	None	None
Sussex	1,795	1,006	904	None	None
Total	3,705	5,188	2,359	10,300	13,680
		30-day maximum			
New Castle	540	5,230	530	15,800	18,800
Kent	1,370	1,460	1,422	None	None
Sussex	1,795	2,070	1,798	None	None
Total	3,705	8,760	3,750	15,800	18,800

[1] Reference: "State of Delaware, Intrastate Water Resources Survey," August 1959.

[2] Assumed 50 gallons per capita per day for those not receiving municipal water.

TABLE 3.—*Ground water inventory, 1957, State of Delaware* [1]

[Gallons per minute]

County	Industrial	Public [2]	Irrigation	Miscellaneous uses [3]
	Maximum			
New Castle	17,405	5,770	See surface	1,478
Kent	19,665	2,830	do	4,430
Sussex	24,779	3,865	do	1,995
Total	61,849	12,465	do	7,903
	Average			
New Castle	8,917	3,770	See surface	1,777
Kent	11,526	2,322	do	2,465
Sussex	17,102	2,801	do	510
Total	37,545	8,893	do	3,752
	30-day maximum			
New Castle	13,127	5,770	See surface	1,230
Kent	16,124	2,830	do	2,465
Sussex	20,970	3,865	do	535
Total	50,221	12,465	do	4,230

[1] Reference: "State of Delaware, Intrastate Water Resources Survey," August 1959.

[2] Includes rural wells.

[3] Includes sources such as military installations not considered in other tabulations.

Our projected needs for the year 2010, excluding industrial, cooling, and steam generation requirements, total approximately 1,400 million gallons per day. If all surface and ground water as indicated previously, were readily availailable for the State of Delaware, we would still receive less than half of our requirements for the year 2010 The only fresh water available to the State of Delaware is the Delaware River. The above estimates were carefully considered; however, we feel they are conservative for the various reasons outlined. More finite evaluations of basic projection rates may result in greater estimates.

TABLE 4.—*Surface water inventory, 1957, State of Delaware* [1]

[Gallons per minute]

County	Industrial	Irrigation [2]	Public
	Maximum		
New Castle	666, 956	77, 175	15, 800
Kent	6, 570	168, 075	None
Sussex	161, 630	78, 750	None
Total	835, 156	324, 000	15, 800
	Average		
New Castle	436, 394	670	10, 300
Kent	4, 250	1, 425	None
Sussex	95, 315	655	None
Total	535, 959	2, 750	10, 300
	30-day maximum		
New Castle	522, 081	17, 150	15, 800
Kent	5, 070	37, 350	None
Sussex	125, 415	17, 500	None
Total	652, 566	72, 000	15, 800

[1] Reference: "State of Delaware, Intrastate Water Resources Survey," August 1959.

[2] Includes ground water.

TABLE 5.—*Summary water use inventory, 1957, State of Delaware* [1]

[Gallons per minute]

Description	Maximum	Average	30-day maximum
Industrial surface	835, 156	535, 959	652, 566
Industrial ground	61, 849	37, 545	50, 221
Municipal surface	15, 800	10, 300	15, 800
Municipal ground	20, 368	12, 645	16, 695
Irrigation ground and surface	324, 000	6, 000	72, 000
Total	1, 257, 173	602, 449	807, 282

[1] Reference: "State of Delaware Intrastate Water Resources Survey," August 1959.

TABLE 6.—*Projected land use for residential, industrial, highway, government and civic needs* [1]

County	1958	1980	2010	2060
	Incorporated areas (square miles)			
New Castle	23. 65	23. 65	23. 65	23. 65
Kent	9. 61	9. 61	9. 61	9. 61
Sussex	16. 85	16. 85	16. 85	16. 85
Total	50. 11	50. 11	50. 11	50. 11
	Subdivisions (square miles)			
New Castle	21. 73	52. 55	94. 60	185. 0
Kent	4. 77	20. 81	42. 70	103. 5
Sussex	4. 57	17. 19	34. 40	78. 4
Total	31. 07	90. 55	171. 70	366. 9
	Industrial (square miles)			
New Castle	24. 64	40. 68	72. 00	176. 00
Kent	. 65	9. 64	21. 90	49. 30
Sussex	2. 17	9. 38	19. 20	37. 96
Total	27. 46	59. 70	113. 10	263. 26
	Government and civic (square miles)			
New Castle	16. 32	16. 61	17. 00	17. 00
Kent	34. 49	35. 98	38. 00	38. 00
Sussex	19. 00	19. 00	19. 00	19. 00
Total	69. 81	71. 59	74. 00	74. 00
	Highway (square miles)			
New Castle	10. 81	14. 70	20. 00	30. 00
Kent	12. 43	14. 79	18. 00	25. 00
Sussex	21. 79	25. 26	30. 00	35. 00
Total	45. 03	54. 75	68. 00	90. 00

[1] Reference: "State of Delaware, Intrastate Water Resources Survey," August 1959.

TABLE 7.—*Summary of land use for municipal incorporations; subdivisions; industrial; government and civic; and highways* [1]

[Square miles]

County	1958	1980	2010	2060	Square miles in county	Potential cropland in 2060
New Castle	97. 15	152. 19	227. 25	431. 65	433	0
Kent	64. 95	91. 99	130. 21	225. 41	592	367
Sussex	64. 38	87. 68	119. 45	187. 21	941	754
State total	226. 48	331. 86	476. 91	844. 27	1, 966	1, 121

[1] Reference "State of Delaware Intrastate Water Resources Survey," August 1959.

TABLE 8.—*Present use and projected needs for domestic water (30-day maximum)* [1]

[Million gallons per day]

County	1958 [2]	1980	2010 [3]	2060 [4]
New Castle	32.80	67.15	114.00	337.5
Kent	7.63	18.91	34.30	92.4
Sussex	6.34	16.33	29.95	73.0
Total	46.77	102.39	178.25	502.9

[1] Reference: "State of Delaware Intrastate Water Resources Survey," August 1959.

[2] 30-day maximum urban average is 100 gpcd, but assumed total at 50 gpcd includes military installations.

[3] 30-day maximum average estimate in 2010 at 125 gpcd.

[4] 30-day maximum average estimate in 2060 at 150 gpcd.

TABLE 9.—*Summary of present use and projected water needs for State of Delaware* [1]*—Industrial water (30-day maximum)*

[Million gallons per day]

County	1958 [2]		1980, ground and surface	2010,[3] ground and surface	2060,[3] ground and surface
	Ground	Surface			
New Castle	18.92	753.00	6,323	13,892	42,488
Kent	23.20	7.31	63	107	374
Sussex	30.20	181.00	1,535	3,340	6,480
Total	72.32	941.31	7,921	17,339	49,342

[1] Reference: "State of Delaware Intrastate Water Resources Survey," August 1959.

[2] These tabulations represent a 100 percent inventory of water use.

[3] Bases for projections are as follows:

(1) Largest potential industrial groups with respect to water use were given separate and detail consideration, namely, chemical, petroleum, steel, and steam generation.

(2) All industries not included under conditions of footnote (a) were assumed, with respect to water needs, to increase by the conservative average of 5 percent per year. This would constitute a 250 percent increase in 50 years.

TABLE 10.—*Total summary water use and projected needs, State of Delaware (30-day maximum)* [1]

[Million gallons per day]

	1958	1980	2010	2060
New Castle:				
Industrial	772	6,314	13,872	42,488
Municipal	32.80	67.15	114	337
Irrigation [2]	24.65	70.49	133	0
Total	829.45	6,452	14,119	42,825
Kent:				
Industrial	30.5	62.78	107	373
Municipal	7.63	18.79	34	92
Irrigation [2]	53.80	110.15	187	622
Total	91.93	192	328	1,087
Sussex:				
Industrial	211	1,534	3,340	7,975
Municipal	6.34	16.35	30	73
Irrigation [2]	25.35	136.05	287	1,113
Total	242.69	1,687	3,657	9,161

[1] Reference: "State of Delaware Intrastate Water Resources Survey," August 1959.

[2] 60-day maximum.

FLORIDA

State of Florida,
Office of the Governor,
Tallahassee, October 15, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

Dear Senator Kerr: In line with your request of June 23, relative to provisions of Senate Resolution 48, Governor Collins requested the Florida Department of Water Resources to contact and summarize the views of State agencies concerned with water resource administration.

As this information has been received during the Governor's absence from the office, I am taking the liberty of forwarding it.

I know Governor Collins greatly appreciated your courteous provision of this opportunity for Florida's views to be presented.

With kind regards, I am,
Cordially yours,

Don R. Livingstone,
Administrative Assistant.

Statement of the State of Florida to the Select Committee on National Water Resources of the U.S. Senate

(Prepared by the Florida Department of Water Resources, October 1959)

INTRODUCTION

In response to the request of the Select Committee on National Water Resources of the U.S. Senate, the Department of Water Resources contacted State agencies known to be interested in the water resources of Florida. Response by these agencies was most gratifying. The information received has been consolidated and combined with basic data already at hand to present a current statement on the status of Florida's water resources—uses, fundamental problems, and needs.

Appended to this statement are copies of the report to the Governor of Florida and the 1957 legislature by the Florida Water Resources Study Commission and of the first biennial report of the Florida Department of Water Resources for 1957–58. The study commission report is a most complete and comprehensive summary of Florida's water resources. Data presented therein still gives an accurate picture of the State's water uses, needs, and problems. The first biennial report presents current information on the status of Florida's waters and some of the administrative problems not touched upon otherwise. The Florida Geological Survey, in cooperation with the U.S. Geological Survey, is the principal water resources data-collection agency. It serves the other agencies in this capacity. Therefore, a copy of the 13th biennial report of the Florida Geological Survey is appended to this report.

Sincere appreciation is expressed to the following individuals and State agencies who assisted in the preparation of this statement through their contribution of material: Dr. A. P. Black, research professor of chemistry, University of Florida; Dr. Thorndike Saville, director, Science and Engineering Center Study, University of Florida; Florida Game and Fresh Water Fish Commission; Central and Southern Florida Flood Control District; State Board of Conservation; Florida Development Commission; Bureau of Sanitary Engineering of the Florida State Board of Health; and the Florida Geological Survey.

WATER RESOURCES OF FLORIDA

In general, the total water resources of Florida exceeds the needs within the foreseeable future if properly managed. The 25-year annual average (1931–55) rainfall is nearly 53 inches. Minimum recorded annual rainfall has been as low as 34 inches in northwest Florida and as high as 90.2 inches along the lower east coast. However, the distribution of rainfall is poor and there are periods when general water shortages occur and local water shortages become acute. On other occasions, the rainfall is excessive and floods result because the existing drainage ways are overtaxed.

During normal years, there is a tremendous quantity of surface water in Florida. An average of about 40 billion gallons per day flows into the oceans, largely unused, but most of this flow is from a few rivers in the northern part of the State. In the peninsula most surface water can be retained in shallow lakes or moves through ill-defined stream beds or canals. The peninsula has a multitude of small lakes and a number of larger lakes. There is reported to be 30,000 named lakes in Florida. Considerable areas of swamp and overflow land currently remain undrained. These lakes and swamps provide a large catchment area which serves to recharge the water table and deep ground-water aquifiers.

The State is underlain by extensive limestone and solimite deposits, quite cavernous, and capable of holding or permitting the flow of tremendous quantities of water. These copious quantities of ground water are available in most locations in the State. However, the quality varies from a water with minimum solids (soft) in the Pensacola area to waters high in minerals (saline) in the lower peninsula.

Florida has 17 of the 100 first magnitude springs. A first magnitude spring discharges 100 or more cubic feet per second. The combined flow of all water from Florida springs has been estimated to average 3,700 million gallons per day. Discharges from the springs range from a few cubic feet per second to more than 800 cubic feet per second.

Normally, the fundamental water problem in Florida is not a shortage of water, but too much water in the wrong place at the wrong time. The problem affects urban and rural areas and influences municipal and industrial use, agriculture, and recreation in all its manifestations.

Water use

The 1957 report of the Florida Water Resources Study Commission presents the most recent data on water use in Florida, which are summarized in the following table:

Water consumption in Florida

	1956 withdrawals		Estimated 1970 withdrawals		
	Million gallons per day	Percent of total	Million gallons per day	Percent of total	Percent increase
Municipal and rural	390	10	790	12	103
Direct industrial	2,227	58	3,420	54	53
Irrigation	1,182	32	2,200	34	86
Total	3,799	100	6,410	100	242

Municipal.—The 1970 estimate for municipal and rural water consumption is based on a population of 6,013,300, of which 70 percent will be urban and 30 percent rural and an average daily per capita urban consumption of 150 gallons. Ground water is the principal source of supply.

Florida's population has grown at a rapid rate of nearly 6 percent per year. Population experts currently place Florida 12th in the Nation (in comparison to 20th in 1950 and 27th in 1940). Population projections prepared by Arthur D. Little, Inc., in 1956 for the State development commission predicted 7,190,000 by 1970. Today, the experts are predicting 8 to 9 million by 1970 and 25 million by the year 2000.

The State board of health predicts that future water use will average nearly 200 gallons per capita per day. At this rate, municipal water needs could average 5 billion gallons per day by the year 2000. This is an increase of almost 600 percent.

Agricultural.—Agriculture is the largest of all water users in Florida. Even with abundant annual rainfall, there is not always sufficient soil moisture at the proper time for optimum crop production. For this reason, irrigation is increasing in importance. A survey of county agents by the Florida Agricultural Extension Service in 1956 revealed that out of 16,584,000 acres of productive farmland and pasture (about 48 percent of the State's total area), about 742,000 acres were subject to irrigation. It was estimated that the average daily consumption of water for irrigation purposes amounted to 1,182 million gallons per day.

The water requirements for irrigation in 1970 or beyond are hard to estimate. However, in reviewing the present trend to supplemental irrigation and water level control on agricultural lands, there will be a continued increase in the demand for water for agriculture. Of the 4,279,000 acres under production in 1956, 17 percent was subject to irrigation. Assuming uniform increases in the acreage of vegetable, citrus, and other crops and maintaining the same percentage irrigated, the estimated water requirements for 1970 will average 2,200 million gallons per day.

Industrial.—Although Florida is 12th among States in population, it is 25th in manufacturing employment. Industry today provides one out of every seven jobs in Florida, a proportion that has not changed greatly in the last 10 years. However, manufacturing is double what it was a decade ago, and as an industrial State, Florida is gaining steadily on the rest of the country.

Industry is not very diversified. About two-thirds of the industrial employment can be found in only five major lines: food processing (including canning), lumber, pulp and paper, chemicals, and tobacco products. The Florida Development Commission believes the makeup of Florida's industry 10 years from now will undoubtedly show electronics, scientific instruments, building materials, metal fabrication, and furniture and fixtures to be much more important than today. However, these particular industries are not generally known as big water users.

The present major industrial water users may be placed in one of four categories: (1) electric power production, (2) pulp and paper manufacture and general chemical industry, (3) citrus processing, and (4) mining. It can be anticipated that the use of water by these industries will increase as the industries themselves expand.

The following table summarizes the water use in these four categories as developed from data submitted to the Florida Water Resources Study Commission:

Principal industrial water use

Industry	Source	Quantity (million gallons per day)	
		1956	Estimated, 1970
Electric power (cooling water)	Surface	1,590	2,120
Pulp and paper and chemical	50-50 surface and ground.	354	770
Citrus processing (canning)	Ground	[1] 94	168
Mining (phosphate)	do	191	[illegible]
Total		2,229	3,421

[1] Calculated estimate for 200-day season is 165 million gallons per day; on annual basis, this would be 94 million gallons per day.

The water use reported by the electric power industry is for cooling water only. The flat topography of Florida does not permit the construction of large hydroelectric generating facilities or the impoundment of large volumes of water. The few small hydroelectric facilities produce an insignificant percentage of the total power generated and are not considered here. Surface water is the principal source (98 percent) of electric power cooling water.

The pulp and paper and chemical industry use large quantities of water. In more recent years, these industries have incorporated better housekeeping and water conservation measures so that the quantity of water used and volume of waste discharged have not increased at the same rate as plant capacity has expanded.

A somewhat similar statement can be made for the food-processing industry. The citrus-canning industry has been making some progress toward reducing the volume and concentration of its waste.

Water used in mining operations is for hydraulic dredging and the operation of the washing and mineral separators. Materials mined include phosphate rock, limestone, heavy sands, and fullers earth. Principal problem relates to the containing of the waste slurry in ponds rather than discharge to streams.

Atomic power.—The lack of native fuels and the relative high cost of power makes Florida receptive to atomic power. Several installations are being considered. One in the Tampa Bay area is expected to be completed by 1963.

At present, sufficient water appears to be available for use in the production of atomic-generated power. Problems may occur in getting the water to the facility and in preventing the destruction of its quality as a consequence of radioactive contamination.

With the development of reactors, it will be necessary to exercise more care and basic control over the nuclear industry in order to protect the water resources and the health and welfare of the citizens of Florida. The State health department is carrying on a good program of monitoring to build up background data.

The State health department has made very fine strides in containing and reducing the municipal and industrial pollution of the surface and underground waters. Basic problem will be to hold onto the progress made, and to prevent further pollution.

There will always be the need to use water for pollution abatement. The health department hopes to continue to be able to use the receiving water for its best intended purpose and to provide adequate treatment in each specific instance. It does not anticipate any increased trends in the use of water for waste disposal. Instead, a higher degree of treatment will be required. Full advantage is being taken of Public Law 660, grants-in-aid for municipal sewage treatment plant construction. Insufficient funds to match local interest or to alleviate problems in defense impact areas continue to be a fundamental difficulty.

Nonconsumptive

Florida's 1,500 miles of shoreline and 1,800 miles of improved waterways, together with the thousands of lakes and dozens of springs already mentioned, have proved to be the topographic features that have made Florida an attractive vacation and residential State. It will be the presence of these natural waterways in a fresh unpolluted condition that will be the key attraction in the future development of the State. Without them, the State would not be Florida—in climate, nor in physical attractiveness.

Florida's waters are used for a myriad of activities. Among the more important are navigation, both commercial and recreational; fishing; swimming; scenic and esthetic enjoyment. It is impossible to arrive at any figures as to the volume of water used for such nonconsumptive purposes.

State and local governments have made concerted efforts to keep up with the demand for facilities. At a recent date, there were 337 public boat ramps and 139 elaborate marine facilities in Florida. It is estimated that more than 250,000 boats will be registered the first year under the recent motorboat registration law.

Navigation.—Florida has 16 seaports, eight with usable depth of 30 or more feet of water. Six ports, three on the gulf and three on the Atlantic, handled over a million tons of commerce each in 1955. Of the 1,800 miles of waterways, the most important commercial waterway is the Gulf Intracoastal Waterway between Carabelle, Fla., and the Alabama State line. Second in tonnage is the intracoastal waterway along the Atlantic coast from Fernandina to Key West.

Use of these waterways, harbors, and rivers and lakes of the State by recreational boating has reached proportions that were not considered probable a few years ago. Even with the extensive waterways, there is a need to plan now to provide waterways for future demands. Completion of the unimproved links of the intracoastal waterway, such as the gulf coast from Carabelle south, would provide both commercial and recreational navigation with a protected waterway. A large part of the area along the route is presently dormant and needs the waterway to aid development of its full potential.

The much talked about, Florida Cross-State Barge Canal would prove most attractive to recreational and commercial navigation.

Recreation.—It is possible to gain an appreciation of the recreational use of the water resources by demonstrating the significance of such use to economy of the State.

The amount of money spent to use Florida's waters for recreational purposes is astounding. The following table summarizes information reported by the Florida Water Resources Study Commission for 1955:

Use	*Estimated expenditure, 1955*
Fresh water fishing	$121, 514, 000
Airboats	1, 036, 000
Waterfowl hunting	1, 500, 000
Recreational boating:	
Maintenance and operation	200, 000, 000
Motors, outboard	6, 500, 000
Boats and equipment	13, 000, 000
Inboard boats and equipment	30, 000, 000
Miscellaneous	5, 000, 000
Subtotal	254, 500, 000
Commercial frog hunting and bait fish	2, 000, 000
Total	380, 550, 000

Continued growth of the recreational aspects of water resource use between 1955 and 1960 would lead to a conservative estimate of an increase of 20 percent (4 percent per year). This would place a current estimate on the value of the industry of almost one-half billion dollars ($456 million) per year.

The pressure on Florida's waters to accommodate the water recreationist will increase greatly in the years ahead.

Central and southern Florida flood control project

As the largest single Federal project in the State, if not the Southeast United States, the central and southern Florida flood control project deserves some special comment. The multipurpose water resource project was authorized in the Flood Control Act of 1948, local cooperation was assured in 1949 and work began in 1950. Originally estimated to cost $200 million, the comprehensive plan authorized in 1954 was estimated to have a total cost of $301,149,900, of which the Federal Government would bear $220,722,010. Congressional appropriations have not kept pace with the planned works or with the capacity of the project to finance them. At present, the Central and Southern Florida Flood Control District provides all lands, easements, and rights-of-way and pays 15 percent of first costs and 20 percent of remaining construction costs. Local interests operate and maintain the completed works upon acceptance from the Corps of Engineers.

The project provides flood protection; water storage during the rainfall season, June through September, for use as agriculture water in the growing season, October to June; fish and wildlife benefits from the extensive shallow reservoirs and recreation values where practically none were anticipated. Project plans have been modified to provide recreation access.

The limitation of salt-water intrusion may effect benefits far overshadowing those attributed to flood prevention. Ground-water demands have increased as the population has grown. Salinity control structures and the large water storage areas in the project have not only checked salt-water intrusion, but actually pushed it back in some areas.

In areas where the central and southern Florida project operates, steps are being taken to mitigate the water problems of supply, demand, and use. The problems are both rural and urban in their compass and it is significant that expansion has already taken place in both areas and further burgeoning is anticipated prior to 1980.

FUNDAMENTAL PROBLEMS

With a normally bountiful supply of water, it would appear that Florida would not suffer from a water shortage compared with other States. However, because of the porous geology of the State and the maldistribution of the supply, both in time and place, Florida has experienced water problems. Too much water in the wrong place, at the wrong time, coupled with the works of man which have endeavored to put the land to new uses and thus unbalanced the natural regime, can be considered the fundamental water resource problem of Florida. A corollary is the need for proper management of the available water resources to obtain the most efficient and best use. To visualize the future needs and plan today for tomorrow, or at least to educate today for a better understanding in order to cope with the problems of tomorrow, is a fundamental need. To do this requires that water resource data be gathered today. The data collecting network must be functioning because average basic data is the result of many years of collection.

Data.—There are several excellent programs currently in operation relating to the physical aspects of water management, including basic data collection. These are supported at different governmental levels from local to Federal. Usually there is a cost-sharing or cooperative arrangement between local and Federal groups.

The total cooperative program by the three branches (surface, ground, and quality) of the Water Resources Division of the U.S. Geological Survey in Florida during 1958–59 was $620,000 of which $313,975 was spent in ground water studies. The program is administered by the Florida Geological Survey.

An expansion of this program and the inclusion of special water studies is greatly needed to aid in the solving of the water resource problems of today and tomorrow.

Fish and wildlife.—The fundamental problems of the fish and wildlife aspects of the recreational use of the water resources concern access by the public to the lakes and streams and the destruction of breeding and food production areas for fish, wild fowl, and game.

With increased development, the lakes are subject to dredging of the shallow areas offshore to fill the marshy edges, rivers are channelized, and swamplands are subject to drainage. These practices destroy the shallow fish spawning areas and the food supply for fish, birds (particularly the wading birds—egret and ibis), and game (ducks and other waterfowl).

Similar practices of urbanization along the coast, in tidewaters, are resulting in destruction of spawning areas for the salt water fishery.

Recreation.—It is not impossible to foresee the day when every available surface acre of water will be called upon to satisfy the recreational urge of the residents and visitors of Florida. Accordingly, a fundamental problem will present itself in the demand to maintain public access to the waterways, especially the lakes; to provide adequate food, boating supplies, housing and sanitation facilities; and to maintain the waters in a condition so that the public can enjoy them free from pollution hazards caused by municipal and industrial wastes.

Pollution.—Industrial and municipal wastes cannot be allowed to damage and destroy the water resources. The problems associated with this aspect of water resource involve the stimulation both by education and finances to provide adequate treatment facilities, and to develop techniques for keeping the gains already made in controlling pollution.

Water supplies.—Water quality is considered by the State Health Department to be its critical water resource problem. The highly mineralized and colored waters in many areas of the State will handicap development of satisfactory public water supplies. It is also believed that desalinization would be a great asset if it can be done so that the water would be acceptable to taste and sufficiently economical.

Financial.—It follows then that funds are required to purchase the solutions which these responsibilities and problems entail. Funds can be obtained at the Federal level only in competition among worthy and authorized projects. It is apparent that local interests and States are to be required to assume a greater proportionate share of project costs. There is no consistent Federal reimbursement policy in relation to water resource development. In general, single projects or single functions within river basins have resulted from piecemeal legislation and administrative decision, rather than from adherence to a congressionally determined pattern.

Therefore, adoption by the Congress of uniform policies for the authorization, financing, and administration of water control projects including definitions of lines of authority between participating agencies is basic to any solution to the water control problem.

CONCLUSION

Blessed with ample water resources for the present, Florida's problem evolves around the effective and efficient administration of these waters for the benefit of all of the people of Florida—present and future. To effectively do this, requires adequate basic data and because of the complexity and side effects of any water resource problem, an interdisciplinary approach involving engineering, hydrology, meteorology, chemistry, biology, oceanography, botany, geology, soil science, economics, public administration, and others. Such an approach is particularly suited to Florida where left alone, there would be no water resource problems. The fundamental problem is man's upset of the natural regime. We can either return the land to nature, or provide plans and works to best use the water resources.

Some problems are statewide, others interstate, but many of the problems are relatively local in nature, involving a drainage basin or less. It has been suggested that these problems can best be attacked by an organized team approach, developed under the auspices of a State agency. They are not suitable for study, nor can they be effectively undertaken by the Federal Government.

Increased support by the Federal Government to its data collecting agencies (U.S. Geological Survey, Weather Bureau, etc.) is greatly needed, as is support for special fundamental studies. A well conceived and adequately supported program could do much to fill the gaps in the knowledge of our water resources.

Florida believes in the policy that water resource development projects should be planned, constructed, and operated by the smallest agency that can efficiently finance and manage the project. The proper role of the State agency should be first to stimulate local interest by offering experienced coordinated advice from all the sources available; secondly to ascertain that local projects dovetail into a coordinated State plan; and thirdly, to offer financial assistance when needed and to insure that available funds are allocated in proportion to the benefits.

These same remarks could be applied generally to water resource management at the national level. Projects wholly within the States and within their means to finance should be initiated, planned, constructed, and operated by State and local agencies. Projects within States that are so large as to be beyond the means of the State to finance, or that for some reason are national in interest, should properly be contributed to by the Federal Government, and might be stimulated by offers of such aid. Interstate projects should be handled by interstate compacts.

Federal participation might best be administered through some type of grant-in-aid program, similar to the cooperative U.S. Geological Survey programs. It is important to retain the greatest possible degree of State initiative and control.

Experience to date has shown that in the development of a cost-sharing or grant-in-aid program, careful attention should be given to spelling out the areas where there will be no cost sharing. As long as local and State interest think that some outside funds will become available, they will not take the initiative of doing it themselves.

GEORGIA

State Game & Fish Commission,
Atlanta, Ga., September 9, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: In compliance with your request for information on water problems in Georgia, a brief summary of present and future water problems with special emphasis on fish and wildlife is enclosed for your information.

Our major problem, as outlined in the report, will be to maintain and increase recreational areas to compensate for an expanding population and an ever-increasing water-sports-minded public. Stream pollution is a major threat to such a program of expansion as it exists in the State at this time. The possibility of reservoir pollution from these streams could make this problem acute in the not too distant future.

In order to accommodate our future fish and wildlife needs, pollution control and abatement will be essential. Unless stern measures are taken and pollution problems dealt with realistically, Georgia will be faced with serious water problems in the future.

Very truly yours,

Fulton Lovell, *Director.*

State of Georgia,
Department of Public Health,
Atlanta, September 15, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: Your letter under date of June 23, 1959, requesting information relative to specific water problems in our State, both present and anticipated to arise between now and 1980, was referred to this office by Gov. S. Ernest Vandiver for the information as requested. This matter was discussed at the meeting of the Georgia Water Resources Commission on July 2 and, in turn, copies of your letter were referred to the following State departments concerned with water resources in Georgia:

Georgia Department of Agriculture.
Georgia Department of Commerce.
Georgia Department of Public Health.
Georgia Department of Mines, Mining and Geology.
State Game and Fish Commission.

A reply to your inquiry has been submitted to you direct by Mr. Fulton Lovell, director, State game and fish commission, under date of September 9, 1959. Replies that we have received from other State departments, as listed above, indicate that they have no specific water problems to report at this time.

As the State agency responsible for administering a water quality program in Georgia, we wish to point out that we do not have any specific water problems to bring to your attention at this time and, further, we call your attention to the water resources study that is now underway in several of the river basins in Georgia by the U.S. Study Commission, Southeast River Basins, as established under Public Law No. 85-850. Much of the information that you have requested will, no doubt, be contained in the final report of this Study Commission to the President.

Sincerely yours,

T. F. Sellers, M.D., *Director.*

A Summary of Present and Future Water Problems and Water Resources in Georgia With Special Emphasis on Fish and Wildlife

WATER RESOURCES

Georgia is fortunate in having abundant water supplies for fish, wildlife, and recreational interests. There are at present, 12 major water impoundments in the State. These areas were constructed primarily for power, flood control, and navigation. From these areas, however, fishing, boating, and recreational use has developed into a multimillion-dollar expenditure each year. Two new reservoirs are under construction at this time and will add to our resource.

In addition to the large impoundments, there are an estimated 40,000 small farm ponds scattered throughout the State that contribute to recreation interests.

Many warm-water and cold-water streams pass through Georgia which also contribute to our sport fishery.

In all, water supply for fish, wildlife, and recreational interests appears to be adequate at this time. We are experiencing a normal increase in population as well as a much greater turnout to water sports. Resident fishing license sales have more than tripled in number during the last 5 years, and although figures are not available for boating, the increase would likely be greater.

Increases of this nature can and in all probability will create a water problem by 1980. Continued expansion and development of new areas, plus better water management for fishing will help to contain these problems and allow for maximum recreation.

SPECIFIC WATER PROBLEMS

As mentioned previously, an expanding population will be a major problem of the future. In conjunction with the need for new areas is the present loss of recreational waters at present through pollution, both municipal and industrial.

Stream pollution at the present level in Georgia is a major water problem. Many streams have been eliminated through pollution and the threat continues.

The problem of expansion and new reservoirs created on polluted streams leans toward aspects of public health and certain loss of these impoundments to fish, wildlife, and related recreation. There are two reservoirs in Georgia now that receive the flow of polluted water. Although the effect on the reservoirs is for the most part negligible, construction of new dams on polluted streams is inevitable, and unless measures are taken, the economic and recreational loss of these areas is a certainty and one we can ill afford in terms of an expanding sport-minded public. Present stream pollution plus creation of many new artificial lakes has turned the public toward reservoir fishing and related recreation. With the increase in population it will be increasingly important to maintain and "clean up" all potential water areas of the State.

Other water problems include loss of commercial fishing in polluted streams, silt pollution from improper forestry and logging practices, and the need for watershed improvement.

HAWAII

State of Hawaii
Executive Chambers,
Honolulu, Hawaii, October 5, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate,
Washington, D.C.

Dear Sir: In response to your letter of June 3, I am pleased to transmit herewith a summary statement on the water problems of Hawaii, both those current and anticipated between now and 1980, together with comments on the solution to some of these problems.

In addition to our summary statement we are also enclosing a report, "Water Resources in Hawaii," published earlier this year which will provide you with detailed information on the water resource problems of Hawaii. You might also wish to refer to "A Report Recommending Continuing Comprehensive Study of the Water Resources of the Territory of Hawaii," 1951, by William E. Warne, Assistant Secretary of the Interior for Water and Power Development. For information on the largest State-owned irrigation project, now under construction, you are respectfully referred to the letter report of the Secretary of the Interior "Molokai Project, Hawaii," House Document No. 415, 85th Congress, 2d session.

The attached summary report points out some of the unusual water development problems in Hawaii which limit the amount of the total annual rainfall that can be economically utilized. For example, there are no large watershed areas or extensive stream systems in Hawaii adaptable to broad river-basin development or multipurpose projects. Rapid runoff of surface water, high permeability of rock formations, intrusion of sea water, and extreme variations in rainfall, pose other development problems.

Notwithstanding these difficulties, Hawaii has a long and proud pioneering history of water resource development dating back more than a hundred years to the time when private enterprise constructed locally the first modern irrigation system for sugarcane. During recent years problems of water resource development and conservation have been given special attention by Hawaii's Governors and legislators. Funds have been appropriated and legislation enacted to provide for construction of government-owned irrigation and municipal water projects, for investigations and research on surface and ground-water supplies, and for the conservation and protection of these water resources.

We fully appreciate the vital role that water will play in further expanding the economy of both Hawaii and the Nation as a whole. To the extent that we may be of help, please be assured of our desire to cooperate wholeheartedly with your committee in its assignment to explore and analyze the Nation's water problems.

Very truly yours,

William F. Quinn, *Governor of Hawaii.*

SUMMARY STATEMENT ON WATER PROBLEMS OF THE STATE OF HAWAII, BOTH PRESENT AND ANTICIPATED TO ARISE BETWEEN NOW AND 1980 WITH SOME COMMENTS ON SOLUTION OF WATER PROBLEMS

Topography, geology, and climatology combine to create problems of water development in Hawaii which are somewhat unusual when compared to those of the other 49 States. Brief descriptions of the physical features and rainfall regimes of Hawaii are essential to provide a proper understanding of these hydrological problems.

Physical features and climate

The State of Hawaii, comprised of eight principal islands separated by a minimum of 10 or more miles of open sea, has a total area of 6,435 square miles. The terrain is somewhat rugged with highest mountain peaks on the various islands ranging in altitude from about 1,300 to almost 14,000 feet. The mountains dominate the topography and influence the climate of the islands, particularly rainfall. The mountain masses are characterized by steep slopes and precipitous sea cliffs on windward exposures while leeward areas tend toward gentler slopes and a greater percentage of usable land.

Although water development problems may be affected or caused by many climatological factors, rainfall is the primary determinant in Hawaii. The mountains act as effective barriers or deflectors of the prevailing northeast trade winds creating precipitation patterns of wide variations peculiar to each island.

Rainfall gradients are very steep, in some instances increasing by 100 percent in a distance of only 3 miles. Rainfall fluctuations from year to year may exceed 300 percent. Also, rainfall intensities are very high, with falls of 12 inches or more in a day occurring at least once a year somewhere in the State. Mean annual rainfall ranges from 6.5 inches at Kawaihae, which is leeward of Mauna Kea on the island of Hawaii, to 461 inches on Mount Waialeale on the island of Kauai. On each of the five largest islands, the annual rainfall ranges from less than 18 inches to more than 250 inches. The median annual rainfall of the Hawaiian Islands is 72 inches, higher than that of any other State and more than double the annual mean of the United States.

Under these conditions of rainfall it might be assumed that Hawaii has no water problems. Such is not the case. The heavy rains of the State occur mostly in the mountains whereas the better agricultural lands are generally located in leeward areas where rainfall is low. About one-half of the State's presently cultivated lands require irrigation on a year-round basis for crop production.

Much of the normally high rainfall of the mountainous areas discharges rapidly down precipitous, short stream courses, often-times through steep narrow valleys ending abruptly at the shoreline. With but few exceptions the construction of dams to provide large impounding reservoirs for surface water is infeasible because of the highly permeable rock formations and the uneconomically small storage capacities offered by the steep and narrow valleys.

Summary of water resources available

The water resources of Hawaii are believed adequate to care for the State's needs for the foreseeable future provided sound development procedures and proper conservation measures are followed. The cost of developing additional sources of water to meet future demands, however, will be higher than that of water developed heretofore. With but minor exceptions, it can be stated that the "cheap" water of the State has already been exploited.

There are very few large streams or other sources of developable surface water in the State which are not now being fully utilized. The remaining few will be developed as demand and economics justify their use.

Some additional water can be developed from the larger basal ground-water supplies (Ghyben-Herzberg lenses) by more complete utilization of these available ground-water sources through better conservation measures and improvements to existing ground-water withdrawal patterns and procedures. Unknown, but probably large, quantities of basal ground water are located in the inland parts of most of the islands, largely under the mountainous areas. Cost of drilling and pumping will preclude development of such water, for many years for economic reasons. Dike impounded or perched bodies of water have been only partially developed to date but remaining sources represent only limited quantities.

Water utilization

Irrigation has been an important factor in the growth of Hawaii's agricultural economy since the first modern irrigation ditch was constructed in 1856. Prior to that time, and for unrecorded centuries, the native Hawaiians had diverted stream water for the irrigation of their taro patches and in doing so established the basic concepts of today's surface-water-rights law in Hawaii. Irrigation has thus influenced the pattern of water development over many years.

The total water use in the State in 1957 was 701 billion gallons, equivalent to approximately 3,340 gallons per day on a per capita basis. The net amount used, equivalent to the total water diverted or pumped, was 590 billion gallons. About 60 percent of the water used came from diversions of surface streams and the balance from subterranean sources. Irrigation accounted for 74 percent of the water use, industrial 19 percent, domestic and military 5 percent, and miscellaneous other uses 2 percent. Approximately 95 percent of the water use in the State was by private agencies.

The table below gives water use data for the State during the year 1957:

Water use in 1957

[Million gallons]

	Kauai	Oahu	Maui	Lanai	Molokai	Hawaii	Total
Distributor:							
Federal	1	9,038	......	......	1	12	9,052
City and county	968	19,044	1,619	......	141	1,162	22,934
Territory of Hawaii	2	1,077	......	......	202	22	1,303
Private	182,923	166,602	224,287	658	712	92,669	667,851
Total	183,894	195,761	225,906	658	1,056	93,865	701,140
Type of use:							
Domestic[1]	3,115	24,410	2,203	90	458	3,880	34,156
Irrigation	156,909	141,835	205,921	522	513	16,129	521,829
Livestock	30	173	25	......	25	154	407
Industrial	23,826	28,429	11,483	46	60	70,794	134,638
Other	14	914	6,274	......	......	2,908	10,110
Total	183,894	195,761	225,906	658	1,056	93,865	701,140
Nature of occurrence:							
Surface	168,520	28,619	129,337	......	412	83,746	410,634
Ground, basal	14,543	149,060	96,092	......	640	8,542	268,877
Ground, all others	695	18,082	477	658	3	1,577	21,492
Unidentified	136	......	......	......	1	......	137
Total	183,894	195,761	225,906	658	1,056	93,865	701,140

[1] Includes municipal and military.

Fundamental problems

Surface water.—Hawaii has ample rainfall but its many steep, short-coursed mountain streams permit diversion of only a portion of the total streamflow. Steep, narrow valleys cut into highly permeable volcanic rock preclude the construction of large impounding reservoirs. Use of stream water is, therefore, largely confined to diversion of dry-weather streamflow and water in excess of the capacities of diversion works and transmission ditches or canals is lost to the sea.

Since areas of use and stream diversion points are usually widely separated, construction of relatively long transmission facilities over difficult terrain has been an economic factor in the utilization of surface water.

Ground water.—Two general types of ground water exist in the State: (1) basal water (Ghyben-Herzberg lens water) floating on and in balance with intruded sea water, occurring either under artesian pressure or with a free water table; (2) dike impounded or perched bodies of water.

The basal water accounts for 93 percent of the ground-water development of the State and includes all of the large sources of ground water. Important basal water supplies are found on Oahu, Maui, and Kauai. Where coastal plain barriers (locally called caprock) have been formed, such basal water occurs under artesian pressures up to 20 or 30 feet.

Salt water contamination presents serious problems in the development of basal water. Under artesian conditions, the fresh water-sea water balance can be easily disturbed or upset to the point of creating critical problems of salt water contamination. In coastal areas devoid of impermeable coastal plains, the thrust and pull of tides in the shore zone of the aquifer causes mixing of the fresh water and salt water. Generally, withdrawal of such water at points inland far enough from the shoreline to avoid this "mixing" is precluded for economic reasons because of the high ground surface elevations.

The value of dike impounded or perched bodies of water, which are usually of limited quantity, lies in their quality, elevation and sometimes favorable location with respect to point of use.

In summarizing fundamental problems, it can be said that the principal problems of surface water development are inability to construct low-cost impounding reservoirs and high cost of transmission facilities; for ground water, the principal problems are salt water contamination and high pumping costs.

Population projection

Any estimates of the future population of Hawaii up to the year 1980 must be considered somewhat speculative. Population projection methods generally considered reliable under normal conditions may be of questionable value if applied to Hawaii at this time because the advent of statehood is too recent to measure its impact on either near-term or long-range population changes. Historically, new States have experienced increased upward trends in population. There is evidence, at least partially verified by short-term figures, that Hawaii will similarly experience an unprecedented growth of permanent residents during the next 20 years. The transient population, represented by tourists, is also expected to increase rapidly due to both statehood and the introduction of fast jet planes between Hawaii and the mainland. The census figures for the 10-year periods 1930 to 1950, and the population estimates for 1959, given below, show the recent trends of population changes in Hawaii.

	U.S. census figures			Hawaii State Board of Health estimates (July 1, 1959)
	1930	1940	1950	
County of Honolulu	202,887	257,664	353,020	466,402
County of Hawaii	73,325	73,276	68,350	59,996
County of Maui	56,144	55,979	48,519	43,275
County of Kauai	35,942	35,818	29,905	27,972
State of Hawaii	368,300	422,770	499,794	597,910

Since World War II the population of the neighbor islands, except Molokai in recent years, has been declining due mainly to the migration of people from those islands to Oahu. There is some evidence to indicate that the declining population of the neighbor islands has reached a bottom and the future trend will be upward. It can be expected, however, that the major increase in population of the State during the next 20 years will be represented by the increase on Oahu.

While estimates of population for the year 1980 can not be reliably projected, it is reasonable to expect that the State's population by 1980 will fall within the range of 825,000 to 1,000,000 people, of which three-fourths or more will reside on the Island of Oahu.

Municipal water use

For the most part, domestic or municipal water systems are operated by the various counties, either directly or through semiautonomous boards of water supply. U.S. military services operate a few systems serving their establishments on Oahu and some minor domestic water systems are operated by plantations or other private companies. There is almost no opportunity in the State for family units to develop ground water of good quality by shallow wells because fresh water occurs only in limited areas where it can be developed at an economic cost. Consequently, most of the population is served by publicly owned utility systems, supplied by water of relatively good quality generally obtained from ground-water sources.

Island of Oahu (city and county of Honolulu)

Although the water resources of this island have been extensively exploited, there still remains some surface water and some ground water that can be developed. It is believed that all anticipated demands on Oahu until some years after 1980 can be met through conservation measures and more complete development of surface and ground-water sources.

The big problem on Oahu is to meet the water needs resulting from rapid urbanization of rural areas of the island. This requires development of additional water and the construction of long transmission mains to convey the water to largely undeveloped "dry" areas such as Ewa-Waianae, Waimanalo, and Koko Head. State subsidies are supplementing water system revenues to finance the construction of two of these major facilities. As urbanization encroaches on agricultural lands, water now being used for irrigation will become available for municipal purposes.

Oahu's challenge to meet future needs of water supplies lies in continuing scientific studies of the causes and extent of salt encroachment and investigations to better determine the nature of and the safe yields of its aquifers; more aggressive action in conserving water now going to waste and in recharging aquifers with surface water; more effective use of its irrigation water and studies leading to more reuse of water and the treatment and use of sewage effluents.

Island of Hawaii (county of Hawaii)

Hawaii, termed the Big Island comprises two-thirds of the area of the State but only about one-tenth of the population. Hilo, its largest center of population, lies in the rain-plentiful Hamakua coastal belt. In the balance of the island, population centers are small and scattered. The problem of supplying municipal water revolves around the high cost of developing meager sources of water and conveying them to distant points of usage. State subsidization is needed and is being given the county in its efforts to develop adequate municipal water systems.

On approximately five-sixths of the island there are no perennial streams that reach the coastline since rainfull rapidly infiltrates the highly permeable and geologically recent lava flows. There is a need to carry out more extensive exploratory drilling programs to determine the location and extent of fresh-water aquifers. Expanded programs for stream measurement and the collection of climatological data are essential for sound water development planning. Cheaper power would make possible the utilization of some deep sources of ground water not now economically feasible for development.

Island of Maui (county of Maui)

This island will probably remain largely agricultural for many years to come although there is considerable activity in developing new resort areas for hotels and for retired persons or vacation sites in beach areas. The island of Maui develops more water than any other island of the State, most of which is used for agriculture. The population is scattered making construction of municipal water systems expensive.

The ground surface is very permeable, limiting the amount of surface runoff and precluding the construction of impounding reservoirs. High ground surface elevations make the development and pumping of water from potentially good Ghyben-Herzberg aquifers underlying inland mountainous areas economically infeasible. Improvements to the Kula water system will require the construction of high-cost lined reservoirs to store the intermittent flash flows of streams in the Waiakamoi source area. The development of potential beach recreational and tourist areas will require long transmission mains for supplying water. Sound planning for future development requires exploratory well drilling and research on methods of waterproofing catchment areas and reservoirs.

Island of Molokai (county of Maui)

This island is sparsely populated but has considerable good agricultural land which is not used to its full potential because of low rainfall. The domestic water problems are largely economic—the conveying of water to scattered population centers. The Molokai irrigation project, now under construction by the State, at a cost of $8 million, will help alleviate water problems by providing irrigation for about 13,000 acres of pineapples and diversified crops. The future extension of this system to divert additional stream and dike impounded water could provide Molokai with ample water to meet all its foreseeable future needs.

Island of Lanai (county of Maui)

Lanai is privately owned and is devoted to the growing of pineapples. Its population is small and centered in one community. It has no serious domestic water problems but could use more water for irrigation. There appears to be very little opportunity to develop additional ground water or surface water. Conversion of sea water appears to offer the best opportunity for supplementing present supplies by sizeable quantities.

Island of Kauai (county of Kauai)

Kauai has the highest annual rainfall in Hawaii and, because of its greater geological age, the highest percentage of surface runoff. The population of the island is scattered but, in general, sources of ground water or surface water are reasonably close to areas of need. There are few major problems of municipal water development on Kauai although there is an urgent need to improve water development facilities and distribution systems to meet potential tourist developments. Some exploratory well drilling to better determine the location and yields of ground-water sources would be highly desirable. Kauai's water supply problems are largely financial.

Island of Niihau (county of Kauai)

Niihau, like Lanai, is privately owned and has very limited sources of water to supply the small native population. Further development of Niihau which would require additional water might have to look to the conversion of sea water.

Agricultural use of water

Agricultural use of water is important to the economy of Hawaii and represents, on a volume basis, the principal use of water in the State. Irrigation of pineapples was started only a few years ago but currently about one-fourth of the

77,000 acres in Hawaii are irrigated. Irrigation of diversified crops will expand. Two State irrigation projects are now under construction and others will be needed in the future to meet farmers' needs. Some subsidization will probably be required.

Irrigation of sugarcane dwarfs all other uses of water in the State, and for that reason is particularly important in the analysis of future water problems of the State.

It seems unlikely that the Hawaiian sugar industry will, in general, require more water than it is at present using. There are some areas now in sugarcane that would benefit by irrigation, or by more extensive irrigation than is now practiced, and some areas not now in sugarcane that could be planted to cane if water were available. The present limitation to the supply of water to these areas is economic rather than physical. Overall, however, it is quite probable that such increases in development as are undertaken by the sugar industry are likely to be offset by decreases elsewhere owing to increasing efficiency in irrigation. Changes in places and methods of development may be expected from time to time in order to improve quality, decrease cost, obtain better storage, decrease transportation, and in general to increase the overall efficiency of water development.

Industrial water needs, electrical energy

To date, Hawaii has had only limited industrialization. Lack of raw materials and high freight rates will probably preclude heavy industrialization, particularly the manufacture of products for export. Ample supplies of brackish water and sea water, and, to a limited extent, fresh water, are generally available for cooling purposes.

Inability to store stream water by the construction of impounding dams limits the extent of hydroelectric power development. Some possibilities exist on neighbor islands for small capacity installations if demand makes their development economically desirable.

Future water demands for miscellaneous purposes

Hawaii has only one navigable river which does not present any serious problems of navigation. Flood control consists mostly of local problems to combat flash floods resulting from torrential rains, which generally do not, but might under certain conditions, fit into schemes of multiple-use projects. Construction of check dams in streambeds or valleys which could provide storage for both the retention of floodwaters and for ground-water recharge purposes have considerable merit and warrant more study and evaluation, particularly for the Honolulu-Pearl Harbor area of Oahu.

In Hawaii, the shore waters of the ocean are widely used for water recreational activities with less emphasis given to the use of fresh-water streams and to the few small lakes found in Hawaii for recreational purposes. This situation holds true also for fish and wildlife.

Means of meeting future demands

Conventional methods.—It is believed that future demands to the year 1980 can be met through various means, including more complete development of presently used sources of water, the development of untapped sources of water, the prevention of waste of water through better conservation measures, more efficient use of water, reuse of water for industrial and agricultural purposes, the transfer of uses from one purpose to better purposes, and the substitution of brackish and sea water for higher quality water.

More effective use of our present supplies can be accomplished through expanded research to increase our knowledge and hydrologic understanding of the State's water resources, particularly its ground-water resources, and by the collection and analysis of more streamflow measurements, well records, and other pertinent hydrologic and climatological data. The development of new sources of water, like the more complete development of water sources now being used, is largely a matter of economics. The development of these sources of water supply will be undertaken when the need for additional water justifies the cost. Such development will depend to a considerable extent on the cost of constructing large transmission lines and/or providing for lined storage facilities.

Heretofore stream water has usually been diverted at elevations high enough to provide gravity flow for irrigation of sugarcane. Many streams in Hawaii are "gaining streams" and have developable flows at lower levels before discharging into the sea. While such water is not always of the best quality, it is susceptible of treatment and use for municipal and industrial purposes.

Leakage of water through surface and submarine springs represents an appreciable loss of water from Ghyben-Herzberg lenses. Reduction of this leakage can be accomplished through better management and control of water withdrawals, the lowering of ground-water tables in Ghyben-Herzberg lenses, and by constructing suitable barriers or other installation to seal off the leakage. Proper installation and location of wells and shaft-type pumping stations would make the maximum amount of good quality water available. Improvements of this kind can be expected with time and a better understanding of our ground-water hydrology.

Surface water diversions represent only a small percentage of the total stream discharges of the State. To increase this diversion appreciably, methods of cheaper storage are required. Low-cost linings to waterproof embankment-type reservoirs or the sides and bottoms of permeable valleys could solve this problem.

Research is needed to determine the type, cost, and effectiveness of small check dams installed in gulches, small valleys, and other intermittent waterways for retention of surface water for recharging ground-water supplies. The effectiveness of wells, pits, shafts, ditches, furrows, and flooded ponds or paddies for recharging purposes should also be investigated under Hawaiian conditions.

Vegetation management

Approximately one-half of the total land area of Hawaii supports forests or mixed forest growth. Most of the State's water supply is derived from this area, either as stream runoff or by infiltration to subterranean aquifers. There are many unknowns in the management of forest reserves for water production where expanded research is needed. What is the relationship between forest cover and water production? What forms or types of vegetation are most favorable for reducing water losses and increasing yield? Do trees add to water yield as interceptors of cloud moisture? Will the use of mountain lands for wood production, grazing of livestock and big game, and other forms of recreational use be harmful to watershed values to the degree that the concept of multiple-use is unworkable.

Weather modification

Results of extensive meteorological investigations carried out locally provide but little encouragement that precipitation can be increased, other than on a very limited scale, in Hawaii by artificial means. A pilot study has, however, demonstrated some success in increasing precipitation by spraying water into updraft cloud formations. There are several sites in the State where favorable updraft cloud conditions exist which, it is believed, would justify Federal sponsorship of a full-scale research project for testing this induced precipitation principle.

Evaporation and seepage control

As most of Hawaii's open reservoirs are used for overnight storage of irrigation water, the control of surface evaporation by chemical means is not a practical solution. Seepage is a much more serious problem in the State and accounts for heavy losses in some instances from reservoirs and unlined irrigation ditches and canals. Economic considerations do not always justify the employment of conventional methods of seepage control through the use of cement, concrete, or asphalt. The development of low-cost seepage control methods would have considerable practical value for Hawaii, both for economic reasons and as a means of conserving the State's water resources.

Evapo-transpiration from soils and vegetation is a major quantitative factor in the State's water budget. Because of wide variations in rainfall, soil conditions, wind exposures, cloud cover, and relative humidities, serious errors can be made in estimating consumptive losses by evapo-transpiration in Hawaii. This is a field where considerable expansion in research could be justified as a means of providing essential information required to properly evaluate and plan for the best utilization of the State's water resources.

Desalinization

When the cost of water desalinization is reduced to the point of being competitive with that for furnishing water by conventional means, desalinization methods will be readily adopted in Hawaii as elsewhere. Ample supplies of both brackish water and sea water are available throughout the State to encourage the demineralization of these sources of water when costs can be justified. Cheaper power, through atomic energy, may speed up the timetable when desalinization will first become economically feasible for the more isolated "dry" areas of Hawaii.

IDAHO

STATE OF IDAHO,
DEPARTMENT OF RECLAMATION,
Boise, November 18, 1959.

Mr. THEODORE M. SCHAD,
Staff Director, Select Committee on National Water Resources,
Care of Senator Robert S. Kerr,
Senate Office Building, Washington, D.C.

DEAR MR. SCHAD: I have discussed the matter of letting Governor Smylie's statement presented to the Senate Select Committee at Boise, Idaho, stand as Idaho's official comments, and he says his statement may be so regarded.

* * * * * * *

Sincerely yours,

GEO. N. CARTER,
State Reclamation Engineer.

STATEMENT OF GOV. ROBERT E. SMYLIE, OF IDAHO, TO THE U.S. SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES, OCTOBER 13, 1959

As Governor it is a pleasure to give you the views of the State of Idaho with respect to the important problem of properly evaluating the use and conservation of our national water resource.

No subject is as important to the West, or for that matter to the Nation, and I am most pleased to salute your chairman's foresight in undertaking this most important and far-reaching study.

As will appear more fully later in this statement, Idaho is in a remarkably fortunate position with respect to water supply. It has been, and will continue to be, a prime objective of the Idaho State government, to protect this water resource and insist on its wise and efficient use. It is the State's most important asset in the developing economic contest that will attend the inevitable growth of the West.

It is my understanding that you do not desire to have specific projects discussed at length in this hearing and for that reason I shall not discuss in detail the immediately interesting proposals which have had consideration in the Congress and in the administrative offices of the Government of the United States.

I should say that we have several projects which have the support of many of our people and the formally stated support of the government of the State of Idaho. These are the Bruces Eddy project on the Clearwater, the Burns Creek project on the South Fork of the Snake, the Mountain Home reclamation project, and the navigation and power dam projects on the lower Snake River in Washington, which would provide water navigation facilities to Lime Point above Lewiston, Idaho.

Now permit me to discuss the water resources of Idaho and their utilization in broader terms.

Idaho as a State government has not, through money appropriations, engaged in the development or utilization of water resources. It has, however, for 70 years lent its encouragement through legislation to water resource development, principally for irrigation use. It has attempted and succeeded to an admirable degree in enacting water laws directed toward equally safeguarding the individual, the corporation, and the municipal corporation, small or large, who is involved in developing and utilizing water.

Notable in Idaho's legislation directed to this end was its acceptance in 1895 of the Federal Carey Act, and the enactment of State laws providing the State legal machinery to put the Carey Act to work. Idaho far outstripped all other

Western States in its irrigation development under the Carey Act, and eventually passed to private ownership something over 700,000 acres of highly productive irrigated land. This land would now command a market value of not less than $400 million.

Coincident with the Carey Act enterprise, Idaho enacted an irrigation district law in 1895 patterned after the Wright Act of California. This made bond money financing available for other irrigation development. Cooperatives and private companies also made some contribution to the sum total of the present application of water to beneficial use by irrigation.

The Federal Reclamation Act of 1902 added some 425,000 acres of new land development to the State, and by the Warren Act, furnished supplemental storage water to a large part of all of the irrigated lands in the State. The Indian Service irrigation operations cover about 32,000 acres of land presently developed, and construction is now in progress for 20,000 additional acres.

Currently, irrigation developed with ground water supplies commands considerable attention. More than 500,000 acres of raw land have been brought under irrigation by pumping from this water source in the last 15 years.

Totaling up, it appears that Idaho's irrigation use of water has developed about 2,700,000 acres of sagebrush into highly productive land producing largely nonprice-supported crops. A conservation present-day value attaching to the land alone is more than a billion dollars. The industry related to agriculture adds a considerable figure to the sum total of the invested dollar values in irrigated agriculture.

To get the full picture of the value of Idaho's irrigated agriculture, consideration must be given to the cities, towns, and villages, which have grown up within this agricultural empire. Stores, markets, banks, small manufacturing and professions—all locate and thrive in the midst of irrigation and power development. Without it, they would be here in only very small numbers.

Since Idaho's admission to statehood in 1890, power development, largely by private enterprise, has kept pace with the need for power. There has never been a power shortage of consequence in Idaho. Boise, the capital of the State, was first supplied with incandescent lighting from a hydropowerplant in 1887. Idaho presently has within its boundaries a total installed hydropower generating capacity, according to the latest figures compiled by the Northwest Power Pool and the Federal Power Commission, of 1,436,000 kilowatts. Additional powerplants are in course of construction. Of this total generating capacity, the Federal Government, acting through the Bureau of Reclamation of the Interior Department, has provided 176,000 kilowatts incidental to irrigation construction. Muncipalities have built 12,600 kilowatts of capacity. The remaining has been built by utility companies which have kept comfortably ahead of the power needs of the State and who are frequently in a position to export power both to east, west, and northwest.

The principal hydropower potentials remaining for future development lie along the Snake River, where it is the western boundary of the State, and on the Salmon River. Opposition of the U.S. Fish and Wildlife Service, national wildlife groups, and differences of opinion between Federal constructing agencies may for a period delay further hydropower development, but when a critical need for more power develops these conflicts of interests will surely have to be compromised to permit the necessary development to proceed.

Manufacturing, relatively speaking, is a minor but rapidly growing activity in Idaho. It has large saw mills, one pulp mill, working mines, fertilizer plants, chemical plants, and numerous food-processing plants. These activities require but a very small fraction of Idaho's water resource. It is doubtful if industrial water requirements will become a problem in Idaho in the foreseeable future. Certainly this will not occur until long after 1980, the date which your committee set as a terminal date for this study.

Idaho's present annual consumptive use of flowing water, confined to the 6-month crop-growing season, is in the magnitude of 5,500,000 acre-feet. Much more than this is diverted from streams and storage reservoirs, probably from 12 million to 15 million acre-feet, depending on how plentiful the supply is in a given year. The great spread between the quantities diverted and the amount used by growing crops is not lost. It finds its way back into stream systems, traveling either on the surface or underground, or replenishes ground-water storage. As an illustration of how this takes place, the Snake River at the Milner diversion dam near Twin Falls, Idaho, is ordinarily held dry from April to October of each year, yet 90 miles downstream it is again a steadily flowing river of some 6,500 cubic feet per second. More than half of this flow is merely water lost to crops through deep percolation into underground reservoirs and channels, or water flowing off the surface from large irrigation projects into the rivers.

There are in operation in Idaho storage reservoirs having an aggregate capacity of 10,400 acre-feet. The larger part of this storage, 7,300,000 acre-feet, was built primarily for irrigation use. However, some of it has power and flood control features in addition to the irrigation use. Reservoirs which have multiple use have an aggregate capacity of 5,245,000 acre-feet. Several reservoirs have three multiple uses—irrigation, power, and flood control. Reservoirs which have no irrigation use and exist for power and flood control only amount to 3,100,000 acre-feet. Only one dam and reservoir has been built in Idaho for the sole purpose of flood control. Its active capacity is 278,000 acre-feet. Eventually a powerplant may be built at this dam and the water also used for irrigation. Most of the feasible reasonably priced storage is now developed. Remaining sites will involve high costs for rights-of-way and for replacement of existing facilities, such as railroad, highways, powerplants, and towns.

Idaho is not presently confronted with the serious water problems that exist in other parts of the United States. There are minor shortages of irrigation water supply in local areas, but they are gradually being remedied by storage construction, where there is storable runoff and where the economics of construction will permit such action.

Idaho enjoys a bounteous surface-water supply. After it has annually absorbed between 5 million and 6 million acre-feet of water in crop production, there still runs out on its western boundary some 66 million acre-feet of water annually. Not all of this water originates in Idaho. There flows into it from Wyoming and Montana, on the average, about 30 million acre-feet each year.

In addition to Idaho's flows of surface water, the State has one of the world's most remarkable ground-water reservoirs beneath the Snake River plains. Estimates of the amount of water thus in storage range from 50 million acre-feet, upward. The annual increment to this vast reservoir is about 1,700,000 acre-feet from leakage from river channels, from precipitation, and from the deep percolation losses which occur throughout the large irrigated areas above the underground reservoir. Other similar reservoirs, smaller in extent, occur in other parts of the State.

Substantial drafts on these ground-water reservoirs have begun within the last 15 years. Currently they are continuing at a surprising rate, considering cost of development, interest rates, power costs for operation, and the uncertainties of crop prices.

Much of the water leaving the State, in the northern part, will never be decreased by a consuming use. Controlling it for power generation and flood prevention are the desirable objectives. On the other hand, southern Idaho has a dryland potential which can absorb an additional 2 million acre-feet of water as fast as the economics of costs and returns indicate the feasibility of this use of water for agriculture.

At present, this further development of irrigation is going forward at the rate of about 40,000 acres per year. Most of this is in small units, 160 to 640 acres each, using ground water for the irrigation source. Financing could be termed private enterprise with Federal Government loans: FHA, SCS, and similar agencies. Some insurance companies have also entered this loan field.

Only one large irrigation development looms in the near future as a prospect. This is the Mountain Home project, whose first unit would water 135,000 acres. Its authorization is uncertain, but it should certainly occur at the earliest possible date. The amount of water it will consume is inconsequential, compared to the principal sources of supply. The Snake River flows alongside the area. There is excess ground water, and some surplus Boise River storage is also included as a partial source of supply for this project. In the ultimate, there is a potential 400,000 irrigable acres in the Mountain Home project area. Possible sources of water supply for the later units are transmountain diversions from the Payette and/or Salmon Rivers. Here again the problems of anadromous fish must have consideration in planning the dams, storages, and diversions which would be a part of the irrigation systems.

It is doubtful in view of governmental history that Idaho will in the near future become a constructing agency after the manner of California and Texas. Such being the case, it appears that future expansion of the use of water for irrigation will depend on how fast Federal financing becomes available and in what amounts. Idaho is taking care of its increasing power needs by private enterprise.

Some of Idaho's flood problems have been met by the building of large storage reservoirs. Palisades Dam on the upper Snake, Anderson Ranch Dam on the Boise, and Cascade Dam on the Payette are examples. But much remains to be done.

Agriculture is, and will continue to be, the backbone of Idaho's economy. Our many agricultural products grow to perfection. They attract processing, canning, freezing, dehydrating, and other food purveyors from all parts of the United States.

Seed growing, garden and field, plays an important part in irrigated agriculture in Idaho. Moisture can be controlled to bring seed to ideal maturity and it is grown in new clean ground. Hybrid seed from Canyon County, Idaho, goes to many foreign countries. Livestock growing absorbs the pastures and forage crops. Dairying looms high in money return to the State's people.

Idaho wants to see more irrigation development become a reality. It has the finest remaining potential in the United States. There are fertile drylands, plentiful unappropriated water supplies, and favorable growing climate. In fact, we have all the requisites to make more irrigation just as successful as the present projects. It only remains to put water on the land. Then homeseekers and nature will do the rest.

Idaho will cooperate in the way of needed legislation as it has in the past. Through its various departments of State, it will encourage and support economically feasible water utilization developments as present economics and the trends of future economics dictate and justify.

We are seeking—we always have been and we always will—the ways and means of developing, comprehensively, every drop of water that tumbles from the snowpacks of these Idaho mountains. And when we have used that water, whether to help grow a potato or to turn a turbine, or both, then and only then, will we willingly send this water flowing into the canyons along our western border to help develop still another empire further west. I could burden you at length with a recitation of our problems, but you must hurry on. Briefly, what I want for Idaho water resources can be summed up in this fashion.

First, our existing agricultural and domestic water rights must have ironclad protection.

Second, our right to make later overriding appropriation of the water that rises on Idaho watersheds for beneficial agricultural consumptive use must never be drawn in question.

Third, in the field of hydroelectric generation of power I want development of these resources, under plans that are irrevocably consistent with my first two stated objectives.

Fourth, flood control can be most effectively achieved in the headwater streams of a watershed. For that reason we can be a maximum help to the downwater States by concentrating on upstream storage.

ILLINOIS

Office of the Governor,
Springfield, October 8, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: In accordance with the request of the Senate select committee, I am attaching a summary of my views in the areas of water resources and control in Illinois. Obviously, in such a condensation of information on these few pages, considerable detail must have been omitted and I shall be pleased to submit further information if it is so desired, and will assist the committee in any possible way.

On behalf of the State of Illinois, the opportunity is appreciated to convey these views to the Senate Subcommittee on Water Resources.

Sincerely,

William G. Stratton, *Governor.*

Illinois has long regarded its water resources as of great value to the growth and development of this State, and within the limits of its Constitution, over the years has created State agencies with duties and responsibilities in factfinding, research, and for regulation of use and development.

Available water resources

A great deal is known about the water resources of Illinois. A typical example is the appended section 1 of an "Atlas of Illinois Resources; Water Resources and Climate," published by a State agency. Much greater detail of knowledge is available than summarized in the atlas. Illinois water resources are as large today as when its area was a wilderness and so far as modern science can determine, they will be undiminished and constantly renewed by a great inflow of atmospheric moisture or vapor pressure in the air which averages 2 billion gallons (2 b.g.d.) per day. About 5 percent of this amount falls as snow or rain which yields an average of 99 billion gallons per day for the State. Evaporation and transpiration from growing plants consume and return to the atmosphere about 76 billion gallons per day; the remaining available amount when added to the minimum flow of record on the State's bordering streams of the Mississippi and Ohio, and diversion from Lake Michigan, brings the grand total mean daily surface and ground water supplies available to Illinois to 43 billion gallons per day. Unfortunately, this water is not uniformly available, either in place, in time, or in quantity. Illinois is peculiarly located geographically and geologically so far as water is concerned. Variations of the water resources are in part due to the great north-south dimension, for within this 385 miles of latitude there is a variation with respect to storm tracts and in distance from the primary moisture source in the Gulf of Mexico. In addition to the seasonal and day-to-day changes, Illinois has experienced occasional extended periods of excess or drought. This has emphasized the fact that while there is sufficient water in Illinois to supply all present needs if it were transported to or located at the points of use. It further emphasizes, however, that regardless of the fact that there is an abundance of water in the rivers and underground supplies of the State, and in Lake Michigan, accessibility and distribution constitutes the major problem in the use of available water resources.

Quality.—Water varies widely in quality and this has been and still is a subject of intensive study through analyses and correlation of thousands of water samples each year. Illinois waters are usually mineralized to a degree, are moderately hard, and may contain iron and various other mineral constituents; however, information on chemical and sanitary water quality is available and chemical, physical, and bacteriological treatment methods are available to adjust any original elements of natural water quality within desirable limits.

Complete knowledge for the full and economic development of water resources requires far more than data on rainfall and streamflow. These include topographic and geologic maps for the location of damsites, rate of evaporation, and sedimentation for the design of reservoirs. Water temperature data are of great importance since the largest single use for water in Illinois is for cooling purposes in industrial processes. Air temperature and wet-bulb data are needed in the design of air-conditioning equipment, another important use of water.

Future water resources needs include an increased and more comprehensive study and the compilation of data on the potential quantity (and quality) of water that will be available, particularly from the ground-water sources in the northern areas of the State.

Present and future use

Paralleling the problems of water resources are those of administration, and control of the uses of such resources. Illinois recognizes the concept of multipurpose use of her water resources and that these uses must include transportation, power generation, industrial (both for processing and cooling), agricultural, recreational, a source of protein food (fish), domestic water supply, and also that its streams must serve as a means for receiving, absorbing, and transporting the spent water supply, or wastes, both industrial and municipal. The present and especially the future problem will be the keeping of such multipurpose uses in relative balance, recognizing that for the health and economy of the State there can be no overuse for any one of the multipurpose uses.

An important test of whether the available 43 billion gallons per day represent a large water resource is to compare this with the present and projected use.

Domestic use for municipalities now totals 1.5 billion gallons per day; this serves 98.8 percent of the State's urban population. Illinois has practically reached the saturation point so far as numbers of municipalities and urban population served by public water supplies. Thus, the future use will be based upon two factors: (*a*) The increase in urban population of the State, and (*b*) the increase in per capita consumption. Based upon the population forecasts for Illinois and the trends and factors involved in the increased per capita consumption, it is estimated that in 1980 approximately 3 billion gallons per day will be needed for use by municipal water supplies.

Industrial use at present accounts for 2.2 billion gallons per day. Thermal electric plants now require 8.7 billion gallons per day; in addition to this actual water use, hydroelectric generating stations within or within the proportion assignable to Illinois on the borders, use an average of 21.2 billion gallons per day. This latter use, of course, only results in loss of head and no withdrawal from the streams. It will be recognized that most water use in Illinois industry (also in municipalities) is nonconsumptive in nature. Although each use reduces the available amount and often affects the change in quality, much of the spent water remains available for multiple reuse before it leaves the State. Future demands for industrial as well as thermal and hydropower generation (including nuclear powerplants) will increase; however, it is believed that the uncertainties preclude any accurate forecast of future water demands by 1980. Based upon past experiences, however, the use of water has doubled approximately every 20 years and we know of no reason why this should not continue in Illinois, particularly as it relates to industry. We believe further that such demands can be met under proper laws, policies, and with reasonable programs of basic data, conservation, and development.

Navigation is an important use of water in Illinois, particularly the Illinois River system extending from Lake Michigan to the Mississippi River. Illinois has 1,147 miles of navigable streams, and present and future navigation in other streams of the State is of interest, as are the bordering waters of the Mississippi, Ohio, Wabash, and Lake Michigan. We believe that such navigable use of water is generally consistent with other uses. Such navigation, we believe, can be maintained without encroachment on other uses and it can be extended as justified without causing shortages in water supplies.

Agricultural uses require 0.1 billion gallons per day at present. It can be inferred from this figure that water for agricultural irrigation does not presently use important amounts of water in this State. Irrigation has been practiced to a limited extent for over 30 years and at the present time there are 338 separate systems capable of supplying 16,500 acres. At present most of this is in specialty crops such as gladiolus, seed corn, horseradish, and truck farms. Irrigation has not yet proven profitable on the two principal crops of the State; namely, corn and soybeans. While there appears to be no rapid spread of irrigation in Illinois, this, however, is one of the great uncertainties in predicting future water requirements for agriculture. The importance of this uncertainty is heightened by the fact that irrigation use is considered highly consumptive, in contrast to the present uses which are largely nonconsumptive.

The recreational use of water is important in Illinois. There are at present over 500 inland lakes and sites for an additional 600 potential lakes. The State citizens at present own over 6 percent of the outboard motorboats in the Nation, which involves an investment of close to $100 million. With the increase in leisure time available, recreational uses of water resources in this State will likewise increase. This use not only involves maintaining water resources adequate in quantity and quality for such recreational uses as aquatic sports but also fishing. This primarily involves the prevention, control, and abatement of water pollution discussed later.

As a source of protein food (fish), Illinois waters are and are anticipated in the future to play an important role. It has been estimated, for example, that for each acre of water, 150 pounds of food in the form of fish life can be produced.

Pollution control

A recognized use of Illinois streams is that of receiving, absorbing, and transporting the municipal and industrial waste products away from their point of origin. The prevention, abatement, and control of pollution of both the underground and surface waters occupies a most important place in Illinois State government. It is recognized that in this field of activity lies the greatest potential for making water available through its reuse. Pollution control in Illinois is considered basic for the conservation, use, and control of this State's water resources. Illinois has pollution laws adequate to cope with its problems. Its administration is centered in the State sanitary water board, an agency created by the legislature, and on which is represented all of the State's interests. This is evidenced by the board's composition of the directors of the State departments of conservation, agriculture, public works, and health, a member representing industry, and another representing municipalities.

Its objectives are served by the following guiding principles: (1) The utilization of our Illinois streams based upon their ability to assimilate wastes, (2) the consideration of the physical, chemical, biochemical, biological, and bacteriological condition, in addition to the hydrologic factors in determining the quality of the outlet watercourse, (3) the recognition that no single standard of quality is applicable to all waters of the State, and therefore, no single standard for treatment of sewage or industrial wastes is applicable to all waste-treatment problems, and (4) the recognition of the economics involved in the treatment of wastes consistent with the usage of the receiving stream.

At present, 95 percent of the State's sewered population is tributary to treatment works and 75 percent of the remaining 5 percent of the population is on interstate waters. Thus, interstate water problems in this area are important. The Ohio River Valley Water Sanitation Compact Commission of which Illinois is a signatory State has demonstrated during its 10 years of operation that such interstate agencies can effectively solve interstate water problems in the area of pollution control. It is conceivable that such agencies could likewise effect the solutions to interstate problems involving the entire field of water resources. The congressionally authorized and approved interstate compact approach would obviate the need of control in the general field of water by the Federal Government. Illinois is also represented on the Great Lakes Compact Commission, the bistate agency which includes the St. Louis-East St. Louis area on the Mississippi, and also participates in a number of other informal gentleman's agreement type of organization with the other States relative to water problems.

In the general area of Federal-State relations, there has been an increasing tendency noted for the Federal Government to exercise control over water rights. We believe that this tendency should be reversed if we are to have any legal order in the area of water resources. We feel that water rights are a matter of State law and that Congress should enact legislation which will make this entirely clear to the Federal agencies and to the courts.

In another area of Federal-States relations, we believe that opportunity should be given for the State's participation during the planning stages of Federal projects. Under the present operating procedure the States are unable to make contributions during the planning stage and subsequent State review is largely perfunctory and is on a take-it-or-leave-it basis.

FACTORS OF PRESENT AND FUTURE IMPORTANCE

We subscribe to the idea that the Senate select committee stress the importance of accelerating programs for securing basic water resource information. This should include geologic mapping, ground-water explorations and studies, streamflow measurements, and studies of chemical and sanitary water quality, sedimentation, evaporation, rainfall, and other meteorological phenomena.

It is evident that our water resources must have a multipurpose use and be used not once but many times before being wasted to the oceans. Considerable research and study is needed before such multireuse can be economically accomplished. There is room for research and demonstration on water conservation at all levels of government by education and by private agencies.

The principle of full multiple use of our water resources should apply to the waters of the Great Lakes as well as our rivers. The State of Illinois recognizes the importance of the Great Lakes for navigation, but we firmly believe that this country must also make maximum economical use of these waters for municipal, industrial, and agricultural water supply. The Great Lakes are far too valuable to be dedicated solely to navigation. The various uses of this resource are not incompatible. It is believed that within the framework of interstate compacts the many problems involving the multiple use and reuse of the Great Lakes water can be resolved.

Illinois recognizes and is attempting to solve varied water resource and use problems which exist today and which can be anticipated. The legislative branch of our State government has kept pace with these problems by enacting legislation for their use and control consistent with our State's constitution. Illinois is attempting to solve and face its future problems with the full cooperation of the various Federal and local agencies as well as the various agencies within the State having duties involving this important natural resource. Illinois has many and varied problems in this field of water resource and use; however, Illinois does not subscribe to the nearly hysterical concern over impending water deficiencies so frequently expressed in recent years. It is believed that through full public recognition and with proper engineering, research, regulation, development, legal and administrative arrangements our water needs can be met so far ahead as we are now able to ascertain. All this we firmly believe can be accomplished within the framework of State government and where such problems assume an interstate nature that solutions to such problems can be found through the medium of interstate compacts.

The State of Illinois appreciates this opportunity to convey its views to the Senate Select Committee on Water Resources, and we shall be pleased to submit further information, if it is so desired, and will assist the committee in any way possible.

INDIANA

State of Indiana,
Executive Department,
Indianapolis, October 1, 1959.

Hon. Robert S. Kerr,
Chairman, Senate Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

Dear Senator Kerr: The State of Indiana made a comprehensive survey of water resources in 1956, with forecasts on requirements to 1975 tabulated. The work was similar in many respects to that now being done by the Senate select committee on a broader scope. Therefore, we are sending 20 copies each of the Indiana water resources report and technical appendix for consideration by your staff.

Recommendations are made that, in general, increases of 1 percent a year from 1975 should be made to project the figures in this report to 1980. An exception to this projected increase should be made for the Lake Michigan-Calumet area of Indiana, where the rate of increase in demands for water will be much larger due to the prospects for a new harbor and extensive steel expansions.

Indiana is proud to be a part of this coordinated study by the Senate select committee. We hope that improvements in the entire water resources program of the United States will be attained.

Attached are replies to your suggested outline of statements. The copies of the Indiana water resources report[1] and technical appendix[1] have been mailed under separate cover.

Most sincerely,

Harold W. Handley, *Governor of Indiana.*

GENERAL INTRODUCTION

Water resources form the base for creation of new wealth, production of foods and fibers, processing, manufacture, and improvement of the domestic living standards in the United States.

Indiana, 39th in size among the 50 States, is among the first 8 both in annual value of farm production and in annual value added by manufacture. It is 10th in population.

The State's increases in these classifications in the two decades 1960–80 are expected to exceed the national averages, due to central location. Its water requirements, therefore, are expected to exceed the national average.

The following statements are in reply to the Senate select committee's general outline of proposed procedures.

DEVELOPMENT OF TECHNICAL BACKGROUND

1. EXISTING SITUATION AND TRENDS IN INDIANA

A. Summary of water resources available

Average annual runoff from rainfall is 220 million gallons per square mile in Indiana. Total State surface is 35,536 square miles. Runoff is larger in the southern half of the State than in the northern half.

Ground water reserves are spotty, but substantial in many central and northern Indiana watersheds and less plentiful in the southern one-third of the State.

B. Withdrawal and use of water

Public water supplies in Indiana number 365. Of these, 47 have surface water as the source of supply and 318 use ground water. Most of the larger cities have turned to surface storage, stream, or natural lake sources. There are 420 municipalities served from the 365 supplies. Many industries depend on wells for their water.

C. Fundamental problems

Lack of balance between supplies of and demands for water remains the big problem. Rainfall is irregular.

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[1] Not reprinted herein.

Periods of drought and of flood have been and are being charted as a guide for future work to assure ample supplies and to prevent flood damages.

The great need is for more development of multiple-purpose projects at all levels of government—local, State, and Federal. Indiana is moving to accomplishment of some major programs of this kind in cooperation with the Corps of Engineers and the Department of Agriculture, as authorized by the Congress. A better coordination should be attained.

Stream pollution has become one of the most important problems throughout the eastern part of the United States and Indiana is well advanced in handling this challenge. Changing population concentrations call for new approaches to prevent pollution dangers.

D. *Ground water problems*

The need for expansion of the ground water inventory activities of the Geological Survey, U.S. Department of Interior, is recognized in Indiana as urgent. Reports by this unit have been outstanding, as have the reports by the surface water branch. But increased demands for water make it essential that much more information on available ground water supplies be obtained.

E. *Water use for pollution abatement*

The design of sewage treatment plants is based on treatment necessary to maintain satisfactory conditions at critical flow of the stream which is used for dilution. However, in many instances during periods of low flow, and in particular in the upper reaches of a watershed and in heavily populated areas, insufficient water is available to maintain satisfactory conditions below sewage treatment plants and industrial outfalls, even with the best of treatment in use today. For example, in the upper White River Basin of Indiana, which contains more than 20 percent of the State population, during periods of low water the flow in the White River is utilized 6 to 7 times in a 70-mile stretch. The requirement for dilution water builds up from the upstream reaches, where 5 million gallons per day additional would be sufficient, on down through Indianapolis where at times an estimated additional 200 million gallons per day would be required for a minimum dilution of plant effluents.

2. PROJECTIONS OF FUTURE DEMANDS FOR WATER AND WATER RELATED ACTIVITIES

The report of the Indiana Water Resources Study Committee for December 1956, and the technical appendix thereto were utilized to project Indiana water use to 1980. Detailed information by subbasins is available in these studies. In most instances, the projected use in 1980 is obtained by multiplying the increase from 1954 to 1975 by 1.24 and adding this figure to the water use in 1954. In the Lake Michigan area the population and water-use estimates were increased in consideration of port and industrial developments.

A. *Population forecast*

The Indiana population in 1980 is expected to be about 6 million. The estimated population for 1980 was obtained by a combination of the population estimates from the 1956 water study report and population studies made in 1958 which indicated that Indiana's population was increasing at a rate of 72,000 per year. However, in the Lake Michigan-Calumet region of Indiana an entirely new city of 100,000 population within 15 years is predicted, in addition to other growth.

B. *Municipal water use*

Projection for municipal water use by 1980 in Indiana indicates an average daily pumpage of 710 million gallons per day and a usage on an average day of a maximum month of 848 million gallons per day.

C. *Rural use of water*

Water use in rural areas is divided into two parts:

(1) The use exclusive of irrigation water for 1980 indicates an average daily use of approximately 199 million gallons per day and a usage on an average day of a maximum month of 277 million gallons per day. This includes rural nonfarm and suburban use, rural farm, and livestock uses.

(2) Irrigation use is difficult to project. However, if the increase was to continue at the same rate that it increased from 1950 to 1954, use by 1980 could be as much as 3,920 million gallons per day during the peak irrigation season. It should be noted that other uses will also be at a maximum during this period.

D. Water needs of industries

The estimated water use by industry by 1980 is 5,125 million gallons per day. This includes an estimate that industry's water usage in the Lake Michigan area would be three times the 1954 usage plus twice the 1954 usage in other basins.

E. Electric energy

The principal use of water in Indiana for electric energy is for cooling requirements of steam plants. The projected use indicates that at least 13,000 million gallons per day of water will be required for this purpose in 1980. The majority of this use will be supplied from Lake Michigan and the Ohio River. Inasmuch as 1 percent or less of this water is consumed, water available for this purpose would be utilized for other beneficial uses.

3. MEANS OF MEETING FUTURE DEMANDS (NEW TECHNIQUES)

A. Conventional methods of adding new supplies and costs thereof

Water, sewage, and industrial waste treatment systems and facilities must be continually expanded and improved to keep pace with population and industrial growth. It is estimated that Indiana municipalities and industries must spend at least $60 million per year, based on present day costs, on water utilities, sewers, and waste treatment facilities to correct deficiencies and to provide for future needs. In critical water areas even these expenditures may not be adequate to maintain water quality suitable for beneficial uses without expensive pretreatment.

B. Vegetational management (reduction of evapotranspiration)

New forage crops are being used to the benefit of landowners in many parts of southern Indiana, where clay soils prevail. The Southern Indiana Experimental Forage Farm, purchased by donations and situated northeast of Jasper, Ind., in Dubois County, is managed by Purdue University and has outstanding research results in reclaiming marginal lands. A pilot watershed in western Indiana is being planned to be the site for comprehensive studies on all phases of soil-water management.

C. Weather modification

Little anticipated benefit from this source can be expected in Indiana due to the close proximity of varied interests in crop production and the lack of ability of weather (or rain) makers to hit target in small plots.

D. Evaporation reduction and seepage control

No detailed work on this has been done in Indiana, but it would provide beneficial data if undertaken on a joint State-Federal basis. Efforts aimed to that goal are being started.

E. Desalinization

Indiana, being inland, has no immediate contact with this research, but the Federal studies and tests of the various methods to reach practical desalinization are being watched with interest as holding promise for benefits to large regions nearer the coasts.

F. New techniques in multiple-purpose river management

Indiana now is engaged in comprehensive development of the river basins in the state, in cooperation with the Corps of Engineers. It also is encouraging and assisting formation of conservancy districts in small watersheds for advancement of well-rounded water-soil projects, as planned by the Soil Conservation Service, U.S. Department of Agriculture.

The major problem is in applying engineering and governmental knowledge already at hand to the accomplishment of coordinated works, rather than in use of any new techniques, as such.

Perhaps one method which may be regarded as new for the purposes of this committee is flood plain zoning. Designations of these areas should be well defined, under local, state and, perhaps in some cases, federal legislation. Indiana has begun work in this phase of flood control.

G. Effects of nuclear energy

Development of nuclear energy for production of electricity will bring a demand for water on an ever-widening scope and in locations where, heretofore, water has not geen available in sufficient quantities to justify the planning of a generating plant. This will call for increased surface water storage in all feasible locations within the watersheds of Indiana.

H. New technical methods of improving water supply

Increased demands for water make it imperative that research be undertaken towards improved methods of water supply and waste water treatment. The following should be considered first for research:

1. New approaches to waste treatment to provide better and more economical removal of impurities, physical, chemical and biological, that are detrimental to water uses.
2. A clearing house for correlation of research projects is necessary to insure early utilization of developments that will improve the total utilization and to forestall unnecessary duplication of efforts.
3. Improved methods of measurement of groundwater resources and rate of recharge under various conditions.
4. Interrelation of surface and groundwater supplies.

SUMMARY AND RECOMMENDATIONS

These points, in summary and recommendations, are presented by Indiana.

SUMMARY

The need for water will more than double in Indiana by 1980, from this date (1959). This is an example of the trend nationally.

On an annual basis, volumes are available to meet these demands—and beyond—but much greater coordination in providing them, as to time and place, is imperative.

This calls for improved, and especially faster, methods for accomplishing projects for basinwide management of water resources in the public interest—including reservoirs for all possible benefits, flood control works, low flow regulation, soil-forest improvements in relationship to water runoff or retention, channel clearance, supplies, and especially pollution control.

Techniques at hand are the result of vast improvements, both in engineering and in equipment, during the last 30 years. They are sufficient to accomplish large scale projects that would meed the water needs of all regions of the United States in the next half century. Research should not be cut back. Rather, it should be continued aggressively on all fronts.

The most urgent requirement is for improved governmental management at all levels—local, State, and Federal—with each of these recognized as having responsibilities in this field due to complexity of the water resources pattern.

Indiana supports the work of the Corps of Engineers, U.S. Army, in water resources projects. We believe that nowhere else in the world is there an agency of such caliber as the Corps of Engineers which works, under congressional direction, to accomplish projects for the up-building of the Nation in peacetime and which is ready, at immediate call, to convert to fighting form in case of any emergency which might threaten the safety of the United States. We believe this to be a truly outstanding exemplification of the American system of government.

Indiana supports the programs of the Department of the Interior, in its scope of operations for improvement of resources management and in natural resources record keeping. Indiana supports the Department of Agriculture, especially in the Hope-Aiken small watershed projects which are aimed primarily at benefits to landowners within the specified smaller, up-valley areas. Indiana now has 30 applications on file for these small watershed programs which are planned and advanced by the USDA Soil Conservation Service.

Indiana supports the activities and objectives of the Federal Department of Health, Education, and Welfare in water sanitation advancements.

Indiana views the minute-by-minute services of the Federal Weather Bureau as absolutely essential to water resources programs.

RECOMMENDATIONS

Coordination in Washington

1. A coordinating commission, with members from departments of Government involved in water resources work as well as regional members appointed by the President with the consent of the Senate, would perform a valuable service as a clearinghouse for all water projects to provide a more orderly scheduling of projects throughout the United States. This Commission could be formed along lines proposed by the President's Water Resources Study Commission. It would submit annual reports and recommendations to the Congress for action on water resources projects, among its duties.

2. Indiana proposes that funds for water resources projects under construction be budgeted in separate legislation and be approved by the Congress and the President prior to the start of each

fiscal year—and that this approval be mandatory by that date each year.

3. Indiana proposes that a bill for authorization of new water resources projects be mandatory each calendar year, as such authorization requests are prepared and cleared by the necessary units of government.

4. Indiana proposes that the Congress enact legislation requiring that an authorization for any water resources project would be terminated 10 years from date of enactment of the authorization if no funds for preparing final designs and specifications had been provided for the project by the Congress in that period.

5. Indiana proposes that the Congress seek means to make records of the Weather Bureau, the U.S. Geological Survey and the Department of Agriculture more quickly available to State agencies in water resources work.

State-Federal relationships

1. Indiana supports strongly the efforts in the Congress to obtain legislation which will clarify and establish the rights of the States to paramount jurisdiction in water rights law. The legislation, H.R. 5555 (Rogers of Texas), is an example of the type which would be desirable in this regard.

2. Indiana has been active in support of compact agreements between the States on water resources problems. It was one of the first States to support the Ohio River Valley water sanitation compact, which has made exceptional progress in pollution control throughout the Ohio River Basin. Indiana, also, is active in support of the Great Lakes Commission as a means of contact between the States for developmental studies and coordination of policies. More recently, the Congress has approved the Wabash River Valley compact between the States of Indiana and Illinois for developmental studies in that basin.

Therefore, Indiana suggests the possibility of the Congress encouraging basinwide compacts between the States, with Federal representation, for the full-scale development of water resources in the respective areas—but without interference with State governmental departments active in this field.

3. Indiana emphasizes that great progress has been made in water resources development throughout the United States in the last 30 years and wishes to point out that, from a peak view, the Congress and all Federal agencies in this work deserve commendations from the public for guidance of these projects which are, truly, an investment in the future of the United States. More efficient methods for local-State-Federal cooperation should be sought, due to the imperative need for action on water resources programs as population grows.

4. Indiana urges strongly that all regions of the United States receive equal consideration in congressional determinations of water resources schedules and financing, with attention to the increasing needs in the eastern part of the Nation being well defined.

5. These recommendations do not repeat several points directed to more technical phases that are included in the text of this report. Furthermore, it is suggested that many technical problems, such as methods for determining cost-benefit ratios on water resources projects, should be referred by the Senate select committee to a special study group for a report back to the Senate select committee. This could be one task for a coordinating commission.

6. Principles, as defined by the Constitution of the United States, should be reviewed repeatedly as guides for keeping relationships between local, State and Federal levels of government on balance in water resources activities that are basic to strength and growth of the Nation.

IOWA

STATE OF IOWA,
OFFICE OF THE GOVERNOR,
Des Moines, December 7, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on Natural Water Resources,
Albuquerque, N. Mex.

DEAR SENATOR KERR: It was a distinct honor for the State of Iowa to have the November 19 hearing of the Senate Select Committee on Natural Water Resources in our State Capitol. I deeply appreciate your generous comment on our presentation.

In compliance with your original letter of June 23, 1959, I am enclosing herewith the formal report setting forth Iowa's recommendations and policy concerning natural water resources.

With sincere appreciation and kind personal regards, I am

Sincerely,

HERSCHEL C. LOVELESS, *Governor of Iowa.*

REPORT OF HON. HERSCHEL C. LOVELESS, GOVERNOR OF IOWA, IN RESPONSE TO A REQUEST FROM U.S. SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES

RÉSUMÉ OF STATE RECOMMENDATIONS AND POLICY

The water problems of Iowa are of national interest and importance because Iowa is a principal food-producing and food-processing State with a capacity for great increases in its output. Iowa is vitally interested in national water resources activities because water is necessary to realize our agricultural potential and the continued expansion of our industrial production. Conservation of water for agriculture, in some instances, tends to diminish the surface runoff needed by some cities and industries and it may be necessary to replace this with water from storage reservoirs, major rivers, or ground-water supplies. Our ground water is unevenly distributed throughout the State and some of it is too highly mineralized for use as it is today. Even with a high degree of sewage and waste treatment, some dilution of wastes are necessary to maintain water of acceptable quality.

Flood protection, transportation, and recreational facilities must be expanded for our increased population, economic growth, and higher standard of living. For these and other reasons, which will be detailed later, Iowa is vitally interested in measures to conserve and improve the water resources within the State and to maintain its rights in water which originates elsewhere but flows through the State or past its borders.

As Governor of the State of Iowa and for the State of Iowa, I submit the following recommendations outlining the major water resources problems within the State. These recommendations are called to your attention in the overall water resources study for the Nation.

Recommendations

1. *Current water resources programs.*—All water resources programs including flood control, navigation, irrigation, power, recreation, fish and wildlife, pollution abatement, municipal, watershed and soil conservation, should be continued, accelerated, and expanded to meet present and future needs. (The listing of water resources programs above and elsewhere in this report is not intended to infer any recommended priorities.)

2. *Basic data.*—The collection and particularly the interpretation of basic information concerning water resources should be expanded so as to provide adequate data for present and future planning.

Ground-water reserves should be located, analyzed, and cataloged as to usability. Surface-water data collection and interpretation should be expanded to provide further information regarding sediment and quality control, and on small drainage areas. The mapping programs (geodetic, topographic, soils, geologic, and cadastral) require immediate attention. Intensification is also needed for meteorological and socioeconomic basic data accumulation.

Only about one-half of 1 per cent of all expenditures for water resources development programs goes into data collection and interpretation. This rate of expenditure is not adequate at present and will not be adequate in the future.

3. *Water rights.*—The Congress should clarify the responsibilities of the Federal Government and the States with reference to distribution of water under the riparian and the appropriation doctrines. Iowa is particularly concerned in the proposed construction with Federal funds of irrigation projects which will enable others to obtain a vested interest and perpetual right in water which is now available for use by Iowans. It is believed that full development in Iowa will produce much more food and fiber per dollar spent and per gallon of water consumed than can be produced by developing new areas.

4. *Canalization of the Missouri River.*—The upstream reservoirs on the Missouri River will do much toward controlling the sediment, as well as regulating the flow. Canalization to Sioux City will give the western areas the full benefit of being located on or near one of the Nation's largest rivers. It will also enable use of reservoir water for other purposes without detriment to navigation benefits. The project will be a major undertaking and should be expedited as rapidly as possible.

5. *Economic studies.*—These should include means of determining the most effective use of water resources through multiple-purpose projects with particular reference to recreation, municipal uses, pollution abatement, flood control, navigation, irrigation, power, and other purposes. For example, a sound method for evaluating recreational benefits is needed in order that projects may be compared, one with another, and so that costs may be equitably allocated. Similarly with other recipients of benefits.

6. *Cost sharing.*—There should be special studies made to determine the most effective means of cost sharing among the Federal, State, and local governmental units, as well as individuals. These studies should consider such costs as those for planning, easements, rights-of-way, construction, operation and maintenance for the various water resources programs. If possible, the financial cost sharing for all programs should be on a uniform basis.

7. *Research.*—Research is needed in many fields. Current projects should be expanded and new ones started. It is being generally recognized in industry that continued and enlarged research programs are essential to progress. It is believed that this is nonetheless true in areas which are largely, if not solely, within the province of government. The following areas in which the Federal Government should have an important interest include:

(*a*) Municipal and industrial wastes: More effective and economical methods are needed for the treatment of municipal and industrial wastes so as to avoid pollution and permit reuse of the water.

(*b*) Evaporation and transpiration: This consumes a large part of the water used in agriculture. Research should be directed toward eliminating loss by evaporation from the ground around plants, and toward development of plants that will use water more effectively than do present species in producing feed and fiber.

(*c*) Evaporation from water surfaces: A large portion of water stored in reservoirs is lost by evaporation. Research in methods of reducing this loss should be continued and expanded.

(*d*) Weather modification: Investigations in this field should be continued.

(*e*) Demineralization and desalinization programs: This research should be continued. It is of importance to Iowa since an appreciable quantity of ground water is highly mineralized and needs treatment for removal of mineral compounds.

(*f*) Ground-water recharge: Research should be initiated to determine effective methods of providing recharge of our ground-water supplies which would be economical and provide safety for human consumption. Such research would also be useful for the storage of water and other fluids.

(*g*) Watershed yield: This may be measured in tons of food and fiber or board-feet of lumber or in acre-feet of water per square mile. Ordinarily, yield of water can be increased by reducing evaporation and transpiration losses. However, it is difficult to do this without increasing erosion, particularly on the loess soils which predominate in Iowa.

Conclusion

We in the State of Iowa recognize the importance of water resources and encourage full development and the multiple use of these resources. This includes the adoption and installation of needed conservation measures on the individual farms, the installation of upstream, and small watershed programs, the construction of needed flood control and storage facilities on the major rivers, and especially the collection and interpretation of necessary basic data to provide adequate information for detailed and complete planning of all water resources activities.

The foregoing recommendations were prepared for the Senate Select Committee for National Water Resources and therefore have dealt with matters requiring Federal action. They suggest that the Federal Government assume a major role in the development of the various water resources activities. I wish to point out, however, that the States, lesser governmental units, and private enterprise also have a vital role to play in the water resources field.

I wish to make our position explicitly clear in regard to State water rights and Federal Government responsibilities. We in Iowa believe that State water rights and laws must be upheld by the Federal Government. We also believe that there are other States rights, responsibilities, and prerogatives in connection with water resources that must also be upheld. By the same token, the responsibilities and prerogatives of private enterprise must be recognized and upheld by both the Federal and State Governments. It is believed that most of the water resources programs referred to in this report should be carried on cooperatively between the Federal, State, and local governmental bodies with each performing its respective duties and responsibilities from the initial planning through the final management phases.

We believe that only through adequate research, detailed planning, proper use, and management of our water and other natural resources can this Nation maintain its strength and position as a world power.

The foregoing recommendations and policy views have been concurred in by the various State agencies and departments having responsibility in the water resources field.

This concludes the résumé of Iowa's recommendations and policies in regard to water resources. Substantiating material for the recommendations and policy views is contained in the remainder of the report.

WATER SUPPLIES AVAILABLE

Ground water

Recent ground-water estimates of the Geological Survey indicate that there is in the order of 100 to 200 trillion gallons of water available in the Jordan Sandstone in Iowa. The amount of ground water available in unconsolidated materials comprising glacial drift and alluvium is unknown, but it is safe to say that there is an amount at least equal to the amount found in the Jordan Sandstone. Large quantities are also available from other consolidated rocks of the State. All of this water, of course, is not economically available for use under present conditions—some being of poor quality, highly mineralized, and unevenly distributed throughout the State of Iowa. Iowa has opportunities to provide large quantities of water for ground-water recharge if economical and safe methods can be provided to utilize some of our excess surface water and could be used by certain industries.

Surface water

The amount of surface water available for use varies from month to month and year to year depending upon the precipitation and the storage available. The average annual precipitation for the State of Iowa during the past 87 years has been just over 31 inches per year. The driest year of record was 1910 with only 19.89 inches, and the wettest year of record was 1951 with 42.22 inches. The precipitation is not distributed uniformly throughout the year with June normally the wettest month, whereas the month of February is normally the driest. In addition to the unequal distribution during the year, the average annual precipitation decreases from the southeast to the northwest part of the State with a high of over 34 inches in the extreme southeast to less than 26 inches in the extreme northwest.

Evaporation and transpiration accounts for 75 percent; percolation into deep ground-water supplies, 8 percent; and stream runoff, 17 percent of our average annual precipitation. Iowa, with its drainage area of approximately 56,000 square miles, loses about 15 to 16 million acre-feet of water annually in the form of stream runoff. There does not appear to be major shortage of water in Iowa, but there are local areas where shortages will occur unless the problems of distribution, management, treatment, use, and reuse are met.

PRESENT USES

Iowa has long been a leading agricultural State and in recent years, industrial development has advanced rapidly to become an important part of our economy. Records for 1958 indicate that there were $2.6 billion of agricultural output and nearly $5 billion of industrial output in the State of Iowa. In order for the State to maintain its position in the agricultural field, and to continue future expansion in the industrial field, sample supplies of water will be necessary not only to take care of these needs, but to meet all other demands.

Farm crops use by far the greatest amount of water in Iowa—20 to 22 inches of water per acre, or 12,500 billion gallons are required annually for normal production. This amounts to more than 20 times all other uses of today combined. Practically all of this water, however, could not possibly be used for any other purpose under present conditions since it is withdrawn from the top 5 feet of soil under normal farm crop production.

The amount of ground water used in Iowa daily, as estimated by the Iowa Geological Survey, is as follows: Municipalities, 100; industries, 180; rural uses (chiefly private domestic), 150; for a total of 430 million gallons. The exact figures are not available on total water used annually in Iowa, but estimates based on the best information available are as follows: Municipal, 55 billion gallons; manufacturing, 135 billion gallons; nonmanufacturing, 390 billion gallons; agricultural uses (excluding farm crops), 55 billion gallons, totaling 635 billion gallons per year. Total use amounts to approximately 0.66 of an inch over the surface area of the State. It is estimated that these uses of water today will possibly double by 1980.

PRESENT AND FUTURE NEEDS

Flood control

Flood control on our border and internal rivers is without a doubt the greatest single need in the water resources field today and perhaps in the foreseeable future. Although the border rivers of Iowa have posed many flood problems in the past, these problems have, to a large degree, been taken care of through the various flood control projects either completed or under construction as authorized by Congress under special legislation. The major flood control problem confronting Iowa today is that of controlling the excessive high and damaging floodflows which occur quite frequently on many of the major rivers within the State. The rainfall pattern for Iowa causes a great variability of flow in most of our rivers and streams. An example of the extreme range from the recorded daily minimum flow to the maximum floodflow on the Des Moines River at Ottumwa, Iowa, is as follows: The minimum flow recorded is 30 cubic feet per second. This represents a variation of some 4,500 times on a drainage area of 13,374 square miles. Many other Iowa rivers display similar characteristics of flow which generally indicates the desirability of utilizing multiple storage facilities to control devastating floods and to provide water to sustain minimum low flows.

Flood control reservoirs

The Coralville Dam and Reservoir, located on the Iowa River and completed early in 1959 by the U.S. Army Corps of Engineers, is the first and only flood control reservoir completed within the State. There are three more flood control dams and reservoirs which have been authorized by Congress. They are as follows: Red Rock, to be located on the Des Moines River above Ottumwa, Saylorville, to be located on the Des Moines River above Des Moines, and Rathbun, to be located on the Chariton River above Centerville, Iowa (see app. A).

There have been preliminary studies made for similar flood control works on several other major rivers, but these studies have not advanced beyond the preliminary stage. Owing to the general topography of our land, the occupancy of the flood plains by cities, urban areas, industries, and transportation facilities, and the intensive farm operations, it is difficult to obtain suitable sites which can be developed economically and provide adequate flood storage capacity. This, however, should not be construed to indicate that serious flood problems and flood potentials do not exist because quite the contrary is true. There is an urgent need for some type of flood control assistance on most of the major rivers within the State and the longer the matter is delayed, the greater the problem will become. Recent examples of flood problems on two rivers are as follows: The 1953 flood on the Floyd River in northwest Iowa took 14 lives and caused $25,602,000 worth of damage. The 1959 flood on the Nishnabotna River in southwest Iowa took [illegible] lives and caused $14,500,000 worth of damage. These two examples are cited only to show what can happen on relatively small river basins when very high intensity rains occur. Flood control measures for Floyd River involving channel relocation, channel improvements, and levees at Sioux City, Iowa, have been authorized by Congress and should be completed promptly. Flood control projects on the Little Sioux River in western Iowa have been under construction for several years by the U.S. Army Corps of Engineers and the U.S. Department of Agriculture. The Corps of Engineers project involves channel improvements and levees on the lower or downstream end of the main river channel. The Department of Agriculture project involved watershed flood protection measures in the upper part of the basin.

As we look to the future, we see the need for well-planned flood control projects on other rivers in Iowa with special efforts made to avoid loss of resources such as lumber, coal, sand, gravel, and rock and to minimize relocation of transportation facilities, urban areas, etc. In order to achieve a balanced water resources and flood control program, the corrective measures would perhaps involve mainstem channel improvements, levees, reservoirs, upstream watershed projects and on-the-farm conservation practices. Each program will need to be designed to fit the specific conditions and problems for the area involved. This will require sufficient basic data regarding rainfall, topographic and geologic maps, soil types, vegetative cover, runoff, hydraulics and hydrologic statistical data, and other related information including economics if effective programs are to be planned. This tends to point out the grave necessity for an expanded and accelerated basic data collection program if our needs of the future are to be met.

Flood plain encroachment

The flood plain encroachment problem in Iowa, and perhaps other States, needs attention. This is primarily a problem for the States but the Federal Government, through its agencies, could perhaps render some guidance, and provide information which would be helpful to the States in solving the important and difficult problem. As we look to the future with knowledge of our increased population, improved transportation facilities, and the need for more agricultural production, the problem of flood plain encroachment will become more acute.

Municipal

Of the 933 cities and towns in Iowa, 702 have public water supplies. These 702 cities and towns serve approximately 62 percent of the population, or 1.6 million people. Most of these water supplies are derived from underground sources, but a few of the larger cities and most of the small towns in the southern part of the State take their water from surface sources such as streams, lakes, and impounded reservoirs. Records from 678 of the municipalities for calender year 1956 indicate that approximately 235 million gallons were used daily. There are 23 municipalities that have surface impounding reservoirs located primarily in the southern part of the State having a total storage capacity of approximately 7,669,476,000 gallons. Seasonal variations in streamflow and years of drought have materially affected the quality and quantity of water taken from surface and shallow subsurface sources. During these periods, it is necessary to transport water to rural areas and restrict uses in the municipalities depending upon their supplies from the surface water and shallow subsurface sources. In the future, these shortages of supply will be felt earlier and more emphatically. Therefore, it will be necessary to provide additional water supplies through enlarged and additional storage reservoirs.

The per capita consumption and use of water is increasing year by year throughout Iowa and the Nation. An example of this trend is shown by the records for the city of Des Moines, Iowa. In 1944, the average per capita consumption per day was approximately 98 gallons, but in 1958, this had increased to 112 gallons per capita per day.

Upstream storage reservoirs now in operation on the main stem of the Missouri River provide water for supplementing low flows on the Missouri River to help care for present and future demands. The same provisions are being carried out in the operation of the Coralville Reservoir located on the Iowa River above Iowa City, Iowa. Similar reservoirs elsewhere in the State would likewise be very beneficial where normal streamflows become too large to provide adequate supplies of water for not only present but future needs. There have been other Federal laws enacted that supplement the flood control law itself in providing for multiple uses of water. As an example, the Water Supply Act of 1958, title III, Public Law 500, enacted by the 85th Congress in 1958, provides authorization whereby additional water supplies may be included in a regular flood control project.

Industrial

Since 1945, industry in Iowa has been making its greatest growth and exceeding the national expansion rate. More than 1,100 manufacturing plants have been established in Iowa during this period creating 40,000 new jobs and increasing the industrial output materially. One of Iowa's greatest needs toward industrial and economical growth, particularly in the western half of the State, is water transportation. This is also a problem to Missouri, Kansas, Nebraska, South Dakota, and other Western States. Statistics illustrating this are briefly outlined in the attached data. (See app. B.)

Navigation

It is a historical fact that markets and industrial growth follow water navigation or cheap transportation. The important impact of the development of the St. Lawrence Seaway will surely be reflected into Iowa and other surrounding States. The completion of a 9-foot channel on the Missouri River to Sioux City and possibly to Yankton, S. Dak., is of prime importance to Iowa and surrounding States if they are to realize the fullest development of industrial and economic growth. Of all the major inland waterways, the Missouri River has experienced the least industrial and economic development to date. The early development of this area will aid materially in checking the migration flow of surplus farm labor and retain many of our well-educated and well-trained men and women in the State. During the past several years, we have been exporting thousands of our better educated and trained citizens (one of our precious resources) to other States due to the lack of comparable jobs in Iowa.

Pollution control

Upstream reservoirs are also desirable in providing water for dilution of sewage and industrial wastes. This should not be construed that sewage and waste treatments should not be provided. On the contrary, the policy of the State of Iowa is to require treatment of these wastes before being discharged into streams or watercourses. However, it must be recognized that complete treatment so as to remove all pollution characteristics, particularly taste and odor creating compounds, is practically impossible. Hence, it is desirable and very necessary in some cases to assure a certain amount of water in the streams for dilution of treated sewage and wastes. As a matter of fact, 342 of the 409 cities and towns having sewage systems also have treatment plants. Many of the existing treatment plants were constructed several years ago and have become obsolete and overloaded and will need to be enlarged and improved.

As near as can be estimated, a total of 225 cities and towns will need either enlargements or replacements to their existing plants before 1980. The total construction value of these projects is estimated at $50 million based on present-day prices. Funds allotted to Iowa under provisions of Public Law 660, the Federal Water Pollution Act, are made available to municipalities to assist with the construction of sewage treatment plants. Thus far, a total of $2,639,000 has been distributed for the construction of 52 sewage treatment projects having a total value of $12,500,000. However, the allotments thus far have not been sufficient to meet the needs. At the present time, there are 44 applications on file for grants totaling $2,770,000 whereas the allotment available is only $896,000.

Agriculture

Iowa, a leading agricultural State, with great capacities for increasing its production, places the water requirements for agriculture as one of prime importance. Special efforts need to be continued to retain as much of the precipitation on the land to meet crop production requirements. The conservation program is designed primarily for this purpose to assist farmers in conserving their soil and water. Thirty percent of Iowa farmers are cooperating in this conservation program. Accomplishments to date are indicated in an attachment (see app. C). A study being made by the U.S. Department of Agriculture will indicate estimates on the needs for the various conservation measures. The results of this study should be released early in 1960 and should be of interest to this committee. Although the results are not available for this report, it may be safe to assume that a relatively small percentage of the conservation measures needed have been applied to date. Efforts should be made to continue the expansion of this program in order to protect our agricultural production by conserving the soil and water resources. There are many cases where the complexity of these problems become so great that the individual farmer does not have the means for combating his problems. The various watershed programs have provided a means whereby Federal, State, and county governments may join with local communities and farmers in solving their problems. They should be continued and expanded. Statistics on the status of watershed programs to date are attached (see app. D).

A special program having some bearing on water resources in our State is that of forestry through the use of adequate forestry plantings. Statistics from a recent forestry survey release indicates that Iowa has 2.6 million acres of forest land. Much of this is contained in regular farm woodlands and shelter belts. The larger portion, however, is found on rugged topography with sharp ridges and deep gullies. There are many areas in the State where forest cover is one of the most effective means of controlling erosion and providing good clear water.

It has been estimated that total farm production within the State could be increased by 20 million bushels of feed grains through the application of the needed conservation measures on Iowa farms. It has also been estimated that 30 million bushels of feed grains could be added through adequate drainage systems, and at least 15 million bushels through supplemental irrigation of 500,000 acres of land where the cost of introducing irrigation would be low ($100 per acre, or less).

Recreation

The demands upon recreational facilities are increasing year by year. The State of Iowa and its citizens have long recognized the importance of water for recreation. This is indicated by the fact that 26 artificial lakes have been created during the past several years providing 4,297 surface acres of water. These lakes are generally located in the southern half of the State to provide recreational facilities in the absence of any natural lakes. The northern part of the State is fortunate in having 67 natural lakes, many of them small but providing 43,019 surface acres of water. In addition to the natural lakes, artificial lakes, and other surface reservoirs, there are many hundreds of miles of rivers and streams existing in Iowa which furnish limited recreational facilities. During periods of below-normal rainfall, the natural flow of many of these streams is quite low and is inadequate to support the desired fishlife. Soil erosion and other types of pollution continue to be serious problems in many of the areas.

The Missouri and Mississippi Rivers provide a great potential in the recreational field in addition to providing water for other important uses. The farm ponds, watershed impoundments, municipal reservoirs, and other impounding structures each contribute to recreational facilities for fishing, hunting, and boating in Iowa. According to "Iowa Official Register," 31 counties within the Des Moines River watershed contain a population of over 799,130 people. Within this area, a total of 200,000 hunting and fishing licenses were sold during the year 1958 and approximately 10,000 boats of various sizes were registered. Without a doubt, these statics, covering only a part of the State, indicate the need for adequate recreational facilities.

It is estimated that total storage available for surface water in Iowa is approximately 510,000 acre-feet including lakes, ponds, and reservoirs.

Special emphases need to be placed on the development of maximum recreational facilities in all water-impounding areas regardless of size. We anticipate that within the next 20 years the increase in population, the shorter workweek, and better transportation facilities will place increased burdens upon the recreational facilities of Iowa.

Appendix A

Flood control reservoir data

Name	Cost	Flood control capacity (acre-feet)	Conservation pool
Coralville Dam Status: Completed.	$15,460,000	475,000	17,000
Red Rock Dam Status: Construction to be initiated in 1960.	71,400,000	1,800,000	50,000
Saylorville Dam Status: Authorized by Congress.	44,453,000	525,000	78,000
Rathbun Status: Authorized by Congress.	18,523,000	327,000	136,600

Reference "Water Resources Development in Iowa," U.S. Corps of Engineer, January 1959.

Appendix B

Industrial output for Iowa [1]

	East half (49 counties)		West half (49 counties)	
	Amount	Percent	Amount	Percent
Population	1,385,839	58	1,009,224	42
Value added by manufacturer	$886,527,000	84	$163,193,000	16
Number employed	113,842	81	26,344	19
Spendable income	$2,492,197,000	60	$1,673,147,000	40

[1] Polk County statistics were excluded from the above summary and are listed separately:

Polk County:

Population	226,010
Value added	$186,425,000
Number employed	22,482
Spendable income	$530,391,000

Reference—"1954 Census of Manufacturers and Sales Management."

Appendix C

LAND TREATMENT MEASURES RELATING TO WATER CONSERVATION APPLIED ON FARMS IN IOWA

Progress to date:

Contouring: 3,087,387 acres.

Terraces: 37,913 miles.

Farm ponds: 10,548, estimated storage totals 41,000 acre-feet of water.

Gully control and watershed stabilizing structures, 4,132: estimated storage totals 45,500 acre-feet of water.

Open drainage (surface drains), 3,618 miles.

Tile drainage, 611,800,034 linear feet.

Drainage ditch construction, 805 miles.

Farm drainage is listed with the water conservation practices. Although drainage as such does not actually conserve water, but through proper drainage, land is made available for agricultural production.

Appendix D

PROGRESS IN WATERSHED PROGRAMS IN IOWA TO DATE

LITTLE SIOUX RIVER BASIN WATERSHED AND FLOOD PREVENTION PROJECT

Size: 4,500 square miles or 2,880,000 acres.

Program progress to date

Watersheds organized	158
Watersheds designated for work plan assistance	56
Watersheds with work plans developed	37
Watersheds treated	35
Watersheds presently under construction	5

Progress in pilot watersheds

Four watersheds were designated as pilot watersheds. These watersheds total 30,133 acres. The structural phase of the program has been completed on all four watersheds. Land treatment measures are continually being applied and evaluation studies are being carried out on two of the watersheds by the Soil Conservation Service (SCS) and Agricultural Research Service (ARS).

Progress in Public Law 566 watershed program

1. Total number of watersheds submitted to date under Public Law 566, 39.

2. Total acres of watersheds submitted to date under Public Law 566, 764, 650.

3. Thirty watersheds have been approved by the State soil conservation committee for planning assistance under Public Law 566, totaling 633,974 acres. Planning has been authorized for 11 watersheds totaling 331,915 acres. Construction has been authorized and is underway in four watersheds covering 46,654 acres. Construction has been completed in one watershed totaling 3,100 acres.

KANSAS

THE STATE OF KANSAS,
Topeka, September 30, 1959.

Hon. ROBERT KERR,
Chairman, U.S. Senate Select Committee on Water Resources,
Senate Office Building, Washington, D.C.

DEAR SENATOR KERR: In response to your letter of June 23, I am enclosing a statement summarizing data on the general water situation in this State. We also are enclosing copies of several reports on the water problems of this State which I feel may be of use and interest to you. This material was assembled by the Kansas Water Resources Board in cooperation with associated State agencies. During the compilation of this material, these offices were governed by (1) the general outline accompanying your letter, and (2) remarks presented by your Mr. Schad at the recent meeting of the Association of Western States Engineers.

Your committee may rely on the cooperation of this office and the various departments of Kansas State government. In this regard, please advise either this office or the water resources board if you desire additional information not contained in the attached enclosures.

Sincerely,

GEORGE DOCKING, *Governor.*

By separate cover:
(1) Summary statement.
(2) Water in Kansas.
(3) Part A, State Water Plan Studies, sections 1, 2, and 3.
(4) Second Biennial Report, Kansas Water Resources Board.

ABSTRACT REPORT OF STATE OF KANSAS TO U.S. SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES

State government activities in the water resources field have been gradually expanding from 1917 to date. Historically, primary emphasis has been on basic data collection and administration of various regulatory laws. Since 1955, following severe floods and droughts of the 1950's, the State has expanded its water planning activities, and now has one agency, the water resources board, devoting full time to this work. Until 1958, the State was, by constitutional language, prohibited from participating in works of internal improvement. An amendment approved at the general election in 1958 relaxes this ban somewhat, but legislation implementing the new amendment has yet to be considered. The State embraces the appropriation law and has approached most interstate problems via use of compacts.

The water supply of Kansas varies tremendously with the western part of the State having abundant ground water and little surface water. In eastern Kansas, ample ground-water sources are scarce, but the surface supply is fairly abundant although most erratic. Average annual export is approximately 12 million acre-feet and there is approximately 200 million acre-feet of available ground-water storage. The bulk of this water is largely undeveloped. However, the potential firm supply from either source is much less owing to erratic fluctuations in the surface supplies (average values have little significance), and the absence of any potential for either natural or artificial recharge in much of the ground-water area. Present State investigations indicate that ultimately the controlling water requirement will in many instances be established by quality rather than quantity requirements. Future water supply needs have not been stressed enough in the development of multipurpose reservoir projects owing to prior limitations in Federal policy, constitutional prohibition on State participation, and lack of either adequate financing or immediate need at the local level of government.

Needed flood control improvements and increased firm surface-water supplies are musts if the economy of the State is to show significant future growth. The magnitude of this task is appreciable as indicated by consideration of the various Federal projects and programs. To illustrate, the estimated cost of completing the several local protection and multipurpose projects either under current study or previously authorized for construction is approximately $700 million. Likewise, ultimate application of the Hope-Aiken watershed program in Kansas could be expected to involve a structural cost of $500 million.

It is believed that most water needs in the foreseeable future can be met by conventional methods. Research directed at reducing evapotranspiration requirements, minimizing water surface evaporation (particularly on farm-pond type structures), and disposal of inorganic wastes appears most desirable. More advanced scheduling of Federal development and clarification of Federal policy and capabilities would allow non-Federal responsibilities to be cast in a far better perspective than is now possible.

Report of State of Kansas in Response to Request of U.S. Senate Select Committee on National Water Resources

I. BRIEF RÉSUMÉ OF STATE ACTIVITY AND POLICY

A. Organization

The development of the water resources of the State of Kansas has been of concern to the people from the time of the first territorial legislature in 1855. The earliest legislation dealing broadly with water resources throughout the State was the act of 1917 establishing a water commissioner whose duties were later assigned to the division of water resources, State board of agriculture. The 1917 act provided the foundation for nearly all subsequent legislation relating to the conservation and utilization of the waters of the State for various beneficial purposes, and during the intervening years much progress has been made in the development of adequate State administrative machinery necessary to cope with the many water problems presented in Kansas. Following the flood and drought period of the early 1950's, the legislature, recognizing the need for increased participation by the State in water resources planning, established the water resources board. This board is solely a planning and policy study organization. As such it is primarily engaged in the working out of water development plans in cooperation with other State, local, and Federal agencies, and in the study of State and Federal water legislation. It is also concerned with the coordination of State water programs, the negotiation of interstate compacts, and the development of interstate or regional water programs. The nature and extent of other water related State activities is illustrated by the following brief summary of agency responsibilities.

The division of water resources, State board of agriculture, administers the laws relating to water use and control of water, and it issues appropriate permits, certificates, and orders covering such items as the construction of dams, acquisition of water rights, and the formation of special water districts.

The division of sanitation, State board of health, reviews plans pertaining to the construction and operation of municipal water supply and sewage treatment facilities, disposal of oil field brine, and treatment of industrial wastes. Extensive testing of both surface and ground waters for chemical, radiological, and bacteriological quality is a continuing function as is the preparation of comprehensive pollution surveys.

Basic research programs of direct interest to water resources development are maintained by the State geological survey, Kansas State University, and the University of Kansas. Water activities of the State geological survey are confined primarily to the study of ground water, but numerous other activities such as topographic mapping are correlated with other water programs. Both fundamental and applied research on the economic and physical aspects of agricultural water problems, climatic factors, and soil classification and management are conducted by the agricultural experiment station at Kansas State University. Study of water as it relates to the overall economic and social environment of an area or region has been of concern in work undertaken at the University of Kansas.

General conservation activities related to water development are exercised by the forestry, fish, and game commission, the park and resources authority, and the State soil conservation committee. The forestry, fish, and game commission develops and manages wildlife areas, and State lakes, administers hunting and fishing laws, and the boating safety law. The park authority is responsible for the development of a State park system and is now in the process of constructing the initial facilities at Lake Kanopolis. The State soil conservation committee supervises the county soil conservation district program, assists with organization and promotion of watershed districts, and processes applications for Hope-Aiken assistance.

B. Basic legal policies

Relative to questions of water rights, Kansas embraces the appropriation doctrine. By legislative action in 1945, all of the waters of the State—surface and ground—were dedicated to the use of the public subject to control and regulation by the State. The basic concept of this law is to assure the potential water user that his investment, already subject to the whims of nature, will be protected against subsequent or presently unforeseen development by others.

Interstate problems of water use have been resolved wherever possible by compact. Compacts have been negotiated with Colorado on the Arkansas River and with Colorado and Nebraska on the Republican River. Negotiations to provide for an equitable apportionment of the waters of the Arkansas River and its tributaries common to the two States are currently underway with Oklahoma. Legislation has also been introduced to secure the consent of Congress to compact negotiation between Nebraska and Kansas on the Big Blue River and its tributaries. Also in the general field of interstate relations, Kansas has participated in the work of the Missouri Basin and Arkansas-White-Red Basins Inter-Agency Committees.

Historically, the State has been prohibited by constitutional language from participating financially in the development of flood control and water conservation projects. In the general election last November, this restriction was removed by constitutional amendment. It is conceivable that this action by the electorate could lead to significant change in State water activities before 1980. However, any legislation implementing this amendment has yet to be considered by the Kansas Legislature.

II. GENERAL DESCRIPTION OF EXISTING SITUATION

A. Water availability

The net regenerating water supply for Kansas is predominately the precipitation that falls within the State. To this is added the streamflow into Kansas from adjacent States and the slow movement of water in some ground water reservoirs that extend across State boundaries. There is also appreciable ground water storage in certain sections of the State; however, a sizable portion of this ground water supply is so situated that there is little significant opportunity for either natural or artificial recharge once the present supply is used.

More specifically, average annual statewide precipitation is approximately 27 inches, varying from less than 16 inches in the western portion to over 40 inches in the southeast corner. Average values are a poor measure of the adequacy of supply and large deviations from the hydrologic norm are experienced. For example, a minimum annual precipitation of less than 5 inches has been recorded at one location and a maximum annual precipitation in excess of 60 inches has also been measured. Similarly, average runoff ranges from 0.01 cubic feet per second per square mile in the western portion to more than 0.80 cubic feet per second per square mile in the southeast. The average runoff leaving the State is approximately 12 million acre-feet (of which slightly in excess of 10 million is self-generating), but the figure has ranged from less than 2 million acre-feet to over 42 million acre-feet.

The total storage in ground water reservoirs in Kansas has been estimated to be about 200 million acre-feet. The largest ground water reservoirs and those capable of the greatest yield to wells are concentrated in the western and west-central parts of the State. In eastern Kansas, large yields from wells can be obtained only along flood plains of the larger rivers and only along the Kansas River do such wells represent a firm supply during extended droughts.

The water paradox of Kansas indicated by the foregoing is amply illustrated by figures II–II and II–IX of the report "Water in Kansas," a copy of which is filed herewith. Those figures graphically illustrate the point that the western part of the State has far less surface supply but most of the ground water, while the eastern part of the State has more abundant surface supplies but meager ground water.

B. Summary of water use

Between 85 and 90 percent of the gross annual supply available is utilized in fulfilling evapotranspiration requirements. Significantly, more than half of this item can rightfully be termed consumptive waste. Based on a generalized statewide survey in 1953, total withdrawals from the net water supplies in Kansas for all purposes—domestic, municipal, irrigation, and industrial—totaled 1,898 million gallons per day of which about 652 million gallons per day were consumed. It was then estimated that by 1975 use would be 4,435 million gallons per day of which approximately 1,395 million gallons per day would be used consumptively. For statistical information and detailed discussion of above, see chapter III of the report "Water in Kansas." (A more thorough accounting of present use and available supplies is now being made in current State plan studies. See copies of secs. 1, 2, and 3 of pt. A, "State Water Plan Studies" filed herewith for a more detailed explanation of this latter program.)

On the basis of the 1953 survey, the total consumptive use for irrigation, industrial, and domestic uses amounted to only 6 percent of the average annual export volume or net supply and 0.6 percent of the average annual precipitation. Also, a significant portion of this was coming from ground water storage. It must be noted, however, that the fresh water supply actually available for perennial consumptive use over and above evapo-transpiration requirements is far less than the average annual export owing to limitations imposed by variability of flow, availability of storage, and important considerations of water quality. To illustrate, recent studies indicate the carryover storage requirement necessary to guarantee adequate yield during extended drought is very severe in Kansas. On some of the streams any attempt to develop a firm yield equal to 30 percent of the mean yield would require total storage capacity of from 6 to 8 times the annual demand and storage sites of this magnitude are most limited

C. General problems of surface water management

As explained above, the variations in precipitation and runoff in Kansas are quite extreme and floods and droughts are common. For example, in the unprecedented flood of 1951, discharges in excess of 400,000 cubic feet per second were measured from a drainage area of about 4,000 square miles. Five years later a city of approximately 10,000 population located on the same stream had to recirculate sewage effluent for a period of several months in order to fulfill common domestic water needs. Obviously such variance in the natural supply has a profound effect on the economy of the State. The report "Water in Kansas," prepared in 1955, estimated that (1) each inch of statewide deficient rainfall caused a reduction of $20 million in annual cash farm receipts in Kansas, (2) average annual statewide out-of-pocket losses from droughts approximated $75 million, and (3) average annual statewide losses from floods approximated $35 million. A subsequent survey indicated that during 1956 Kansans spent more than $10 million in hauling water to the farms and ranches of this State.

In terms of surface water management, it is apparent that regulation by both temporary and carryover water storage is especially valuable in Kansas as a cushion against the feast and famine extremes in the natural supply. Although it appears possible to develop a significant amount of storage in Kansas, it must be recognized that the topography of the State provides but a limited number of good reservoir sites. Flood control storage has been stressed to date, primarily because of the immediate need for flood control and the Federal assumption of appreciable responsibility in this field. As water demands continue to increase to the point where natural firm yields become most inadequate, more emphasis on water supply will develop and in some instances conflicts in storage use will occur. Future water supply needs have not entered into reservoir planning to the degree believed desirable owing to several factors including limitations on this field in federal policy, prior constitutional prohibition of State participation, financial credit problems of local governments, etc. (This matter is discussed in more detail in the accompanying copy of the Second Biennial Report of the Kansas Water Resources Board.) State planning studies now underway are attempting to fix the potential storage capacity and ultimate firm yield potential of the various streams and basins in the State.

D. General problems of ground-water management

Perhaps the greatest single problem involved in ground-water management is that of obtaining sufficient basic information needed to delineate the location, extent, and quality of the available resource. Equipped with such information, ground-water management problems can be approached in an intelligent way. Lacking such data, only the painful process of trial and error remains. Suffice it to say that present knowledge of the location, extent, and quality of available ground water is limited. The need for a more extensive ground water investigative program is becoming even more apparent with the recent and rapid growth in the ground water usage, particularly for irrigation. There is one long-range problem of appreciable concern. In much of the extensive ground water areas of western Kansas, there is little opportunity for either natural or artificial recharge. Practically any use therefore represents a condition akin to mining. (See Second Biennial Report, Kansas Water Resources Board.) Although the present supply in these areas is tremendous, the long-term outlook is adverse.

E. General problems of water quality

Kansas water supplies either are or have been affected to a certain extent by both natural and manmade pollution. The State has made good progress in attacking the pollution problem, but there is still work to be done. In Kansas, with its limited water resources, no water is used for pollution abatement in lieu of treatment. The State cannot afford to dedicate any of its streams to use as open sewers, and treatment of domestic and industrial wastes is required regardless of location. It is essential that all wastes be adequately treated since, even with complete treatment, dilution water will be required in streams so as to maintain adequate quality for reuse downstream. Minimum or low-flow requirements based on needs for dilution water, present and estimated future, have been established for most of the streams. (For example, see secs. 1 and 3 of current "State Plan Studies.") The State plan studies now underway indicate that this post-treatment dilution requirement will in many instances be the governing factor in determining reservoir storage needs; and the degree to which such flows can be provided will undoubtedly fix to a large extent the ultimate economic development of the area, hence the State. Ultimately, subsequent technological advancements in waste disposal will be needed to permit economic growth beyond that possible under present outlook.

GENERAL COMMENTS ON FUTURE DEMANDS

At present only generalized statewide estimates of future demands can be presented. They are based in large part on the data presented in "Water in Kansas." More detailed studies now underway reflect some departure from this data but statewide refinement is not possible at present.

A. General municipal needs

In 1953 the 426 public water supply systems in Kansas furnished an average of 203 million gallons per day to 1,283,000 persons. About two-thirds of this supply came from ground sources, and about one-third of the total use was consumptive. The 1975 requirement of Kansas public water supplies has been estimated by the municipal departments to be 335 million gallons per day. In total this estimated increase would be comparable to assuming a 25-percent increase in population served and a per capita daily use of 185 gallons per day as contrasted with a present average of 155 gallons per day. Both figures appear to be reasonable projections on the basis of present trends.

B. Agricultural use of water

In 1954 it was estimated that 420,000 acres of land were under irrigation and it was predicted ("Water in Kansas") that by 1975 as much as 1 million acres might be irrigated. In a dry year such a demand would require approximately 2,500,000 acre-feet of water. Current indications are that this estimate may be most inadequate. Irrigation expanded rapidly in 1955 and 1956, and steady growth for some time in the future is to be expected. A 1980 figure of 2 million acres would not be impossible. It appears doubtful that more than 10 percent of this irrigation would be represented by organized surface water district operations. On the other hand, an appreciable percentage of the irrigation water will be extracted from ground water sources. Hence, statewide, the major irrigation impact in the next 20 years will probably be that of depleting ground water reserves with a smaller effect on potentially available surface water supplies. Total livestock and rural domestic use is relatively small, and the problem is not one of overall magnitude but rather one of stability. Particularly is this true where one must rely on surface supplies or shallow groundwater sources. Both irrigation and domestic requirements are minor when compared to the basic evapo-transpiration requirements of dry land agriculture. (See table III–i, "Water in Kansas.")

C. Water needs of industries

Present industrial water use in Kansas including that for electric generation is largely nonconsumptive because most of it is for cooling purposes. In 1954 it was estimated that gross withdrawals approximated 1,000 million gallons per day. The requirement for 1980 might double or even quadruple current needs. Because of the need for reuse in this State, it is quite likely that the greatest industrial impact on water supplies will be reflected in the minimum flow requirements necessary to adequately transport and dilute the treated return flows of industry.

D. Navigation

No instate navigation requirements are visualized prior to 1980. Of importance to Kansas is the maintenance of adequate flows in the Missouri River for full-scale navigation operations. Although the Missouri River borders only a small segment of northeastern Kansas, a very significant portion of the available facilities of all forms of transportation needed to convey and distribute both inbound and outbound products in Kansas funnel into this area.

E. Flood control

Flood control represents a continuing need at present and in the anticipated future. This need must be resolved as rapidly as possible commensurate with other factors such as resolution of differing public viewpoints, the relative need of other public works at all levels of government, the ability of local units to assume assigned responsibility under Federal programs, etc. Certainly, Kansas has flood problems, and the many projects necessary to alleviate same are viewed locally with the same degree or urgency in each affected area. Seldom are these problems of a nature that can be resolved by a single individual or corporation. Some degree of understanding of the widespread need and public desire for control can be obtained by examining figure 3 and tables I and II in the second biennial report of the water resources board. Shown therein is a summary of the current status of the many local protection and major reservoir projects which are either under current study by a Federal agency or previously authorized for construction. The estimated cost of completing such work is approximately $700 million. The small percentage of completed projects as shown therein indicates the relative need that remains. Data contained in the same report relative to the USDA watershed program is no longer current. As of July 31, a total of 26 applications involving approximately 2 million acres had received State approval for planning assistance. Of these 26, some 15 watersheds had been authorized for planning by the USDA, planning had actually been initiated on 12 (3 of which were subsequently suspended) and construction operations approved for but 3 (2 are very small) projects. It is to be expected that approximately 10 more projects involving an additional 1,500,000 acres will be applying for planning assistance next year and at least 12 more watersheds encompassing still another 2 million acres are initiating organization procedures under the State Watershed District Act. It is conceivable that the program as now proposed would be applicable to still another 10 to 15 million acres of land in Kansas. Federal costs for the structural program alone could be expected to approximate $125 million for those watersheds now organized or in the process of organizing and for ultimate coverage structural cost might well approximate $500 million. Whether any significant portion of these Federal programs become reality will depend on (*a*) whether or not the Federal Government is prepared to continue programs of this scope, and (*b*) whether local or possibly State interests are able to meet the non-Federal obligations involved. In any event, it is quite obvious that whether major reservoir, local protection, or watershed projects are involved, the flood control demands to be met by 1980 will be largely determined by the public funds made available for this purpose and related multipurpose reclamation or water supply projects.

F. Water recreation, fish and wildlife

Although combined local, State, and Federal efforts have made significant advancements in providing water-based recreation in the State, the demand far outweighs the available supply. Natural lakes are practically nonexistent and few streams may be considered as perennial. More than 40 State lakes averaging approximately 200 acres have been constructed. In addition, between 15,000 and 20,000 acres of water area have been provided in the wildlife refuges. Also the 7 completed Federal reservoirs provide approximately 27,000 acres of water area, but few of those constructed to date are advantageously situated to serve the major population areas. Development of the reservoir and watershed projects listed in the foregoing section will improve materially and opportunity for water-related recreation in this State.

G. Water for waste disposal

Because of the inland location of the State and the limited availability of firm natural supplies, the use of complete waste treatment facilities is dictated at practically all locations. Nonetheless, dilution or minimum flow requirements needed to assure sanitary conditions and proper chemical quality during drought periods appears to be the critical water requirement in considering the future economic growth of the State. (See sec. 3, pt. A, State Water Plan Studies.) Future effects of consumptive depletion will tend to make the problem more serious; however, the major problem stems from natural-flow deficiencies. It is most probable that this need will lead to a necessary revision in present storage allocations in a number of reservoir projects or to the development of adequate supplemental storage. A few selected examples of the basic problem presented are illustrated in the following table:

Town and river	Drainage area, square miles	Average flow, cubic feet per second	Minimum desirable flow in cubic feet per second [1]		Natural flows			
					2 percent chance drought condition		5 percent chance drought condition	
			Present	1975	30 days	6 months	30 days	6 months
Lawrence-Kansas River	58,420	5,850	750	1,500	175	410	290	570
Independence-Verdigris River	2,892	1,522	10.3	13.2	dry	0.2	dry	2.2
Coffeyville-Verdigris River	....	....	42.4	48.4	dry	0.2	dry	2.2
Ottawa-Marais des Cygnes River	1,250	541	7.0	14.1	dry	0.5	0.1	1.1
Osawatomie-Marais des Cygnes River	1,658	795	1.7	2.9	dry	0.3	dry	2.3
Wichita-Arkansas River	40,420	849	200	....	6	26	10	39
Eldorado-Walnut River	435	150	33.3	40.5	dry	0.3	dry	1.5

[1] Based on adequate treatment facilities installed.

MEANS OF MEETING FUTURE DEMANDS

A. Conventional methods of adding new supplies

It would appear that most Kansas water needs for the future can and will be met by the use of presently known and perfected conventional methods. There will be increasing emphasis on the need for conservation or water supply storage in reservoir projects because of the limited number of sites, and the need for maximum development if the water resources potentially available are to be fully utilized. The fact that most of the increase in the net usable supply during drought periods must come from carryover storage of floodwaters and the necessity of using sizable structures to accomplish this result will probably mean that fewer projects will be within the means of individual communities or industries and that groups of water users will have to band together in some sort of watershed, water user, or conservancy type organization to promote, construct, and finance large water projects. Although there is a possibility that ultimate development will require some transbasin diversion of water, the need for such activity prior to 1980 will be relatively small. Adoption of the recent State constitutional amendment may make it possible for the State to participate in some of these undertakings. At present there is a pronounced gap in water supply development for future needs owing to local financial limitations and the absence of action by either State or Federal Government.

B. Vegetational management

The one area of the water budget where any measurable progress would have a significant result on the available water supply is that involving evapo-transpiration. Research directed at reducing the land evapo-transpiration requirement in the plains area has been more or less nonexistent. Yet for every percent reduction in this requirement, almost 10 percent increase in available net supply for other uses would result. Whether such a solution is possible is not known but the potential benefits are too great to dismiss this concept as being absolutely impractical. The State Experiment Stations Division of the Agricultural Research Service, U.S. Department of Agriculture, has submitted to Congress a request for $5 million to conduct basic research on soil, water, and plant relations. Broken down among the various States, such a request would permit only a limited start in needed investigations, but nonetheless it is believed to be a step in the right direction.

C. Weather modification

To date, results of cloud seeding in the plain States are not viewed as promising nor conclusive. Admittedly the data is meager and further research is desirable. The direct relationship between adequate precipitation and cash farm receipts makes the subject of interest to Kansas although a reduction in plant water intake needs via other research efforts may well provide the same end result. Perhaps the phase of weather modification and research most vital to Kansas as viewed from combined water and agricultural management problems is that concerning long-range forecasts. Every advancement in this area is a step in the right direction.

D. Evaporation reduction

Water loss by evaporation from open water surface is a major problem in Kansas. Annual loss has been estimated at 300,000 acre-feet and will increase appreciably as continued reservoir developments of all sizes take place. The development of practical methods of applying monomolecular films to reduce evaporation losses (as presently being investigated by the Department of Interior and others) would be of great benefit in Kansas. Because of the potential value of the water that might be saved, Kansas is solidly in support of continued research and investigation in this field. The excessive water hauling costs cited earlier focuses attention on the need for evaporation control on the farm pond-type structure. Here the wind factor, which has been a problem in the large reservoir research program, is minimized and Kansas would urge that consideration be given to perfecting management techniques on the small structures so that results of the research program can find earliest possible field application.

E. Desalinization

As a long-range project, Kansas heartily endorses the basic research and applied pilot investigations currently underway on the conversion of saline water. However, even with the use of the most optimistic cost figures now available for producing fresh water from saline or brackish waters, it does not appear that this process will find practical application in this part of the country within the next 25 years. There are many existing conventional sources of fresh water supply in this State which are not yet fully used and which may be developed at costs much lower than those currently visualized for salt water conversion. At present this appears to be true even if the water supply is many miles from the point of use. Kansas would urge that continued research include consideration of the problems of waste disposal associated with such conversion. This disposal problem is not unlike that now encountered in the production of oil, and past experience has indicated the need to meet disposal needs adequately if fresh water is to be protected. Until overall program costs, including proper allocations for power requirements and waste disposal, are competitive with other conventional water supply developments, the applicability of conversion to this part of the country is inappropriate.

F. Hydrologic and economic basic data programs

As water demands increase, the need for refinement in hydrologic information will increase accordingly. Responsibility for fulfilling this need must rest largely with government—State and Federal. In the past 4 years, Kansas has made significant advancements in some of these programs, notably stream gaging, ground water investigation, topographic mapping, stream sediment investigations, and the monitoring of water quality. Nonetheless, further advancement in all of these programs is desirable. There are four areas where accelerated Federal assistance would appear desirable. An accelerated topographic mapping program, which serves many useful purposes over and beyond water development, would be desirable. Such a program is vital to water development in many ways, not the least of which is the location of potential surface storage sites. Ultimately the economy of this part of the Nation will be limited by the firm water supply, and there is need to ascertain, within reasonably narrow limits, the storage potential available. A second area is that of basic research which will tend to conserve and lengthen the life span of the available ground water resource in the Great Plains area. Is it possible to develop a high value, small acreage (at least small water requirement) crop which will overcome the marketing problems of the area, provide economic stability in times of drought, and reduce the huge water requirement now necessary to provide such stability via irrigation of wheat, sorghums, cotton, and so forth. A third area of need involves the collection and interpretation of economic base data on the relative value of water for various purposes. Such data must incorporate regional and national marketing and resource factors as contrasted with solely local evaluation of the problem. Finally long-range resource development, including but not limited to water development, requires adequate knowledge of management requirements and productivity characteristics of the land resource. Hence, an accelerated soils mapping program would appear to be in the national interest.

G. Comprehensive water accounting

A continuing program of analysis of water availability and water demand is believed a must. It is assumed herein that primary responsibility for administering water use will remain with the individual States and hence basic responsibility in this general planning phase should rest with the States. Kansas has initiated such a program during the past 3 years and in that short time, critical examination of such items as foreseeable water requirements, and the relative frequency and extent of droughts in unregulated flows have served to crystallize thinking on water supply storage needs and to focus attention on attendant financial and legal problems. Such programs are needed to complement the individual project planning of Federal development programs and local proposals for water use.

H. Long-range water supply policy

Historically there has been a need for incorporating long-range water supply considerations in basic governmental policy relating to resource development. Local units of government and/or private development corporations face serious financial limitations. Also in many cases, water supply needs have not been as urgent as other functional requirements and hence neither local thinking nor governmental development policies have provided for maximum water management. Accordingly, reservoir sites have often gone underdeveloped. The Federal Water Supply Act of 1958 was a welcome step in the other direction. The usefulness of that act, however, will depend on (*a*) positive congressional recognition of State water laws and the provisions of interstate compacts, and (*b*) reasonably liberal interpretation of the non-Federal assurances requirement for at least a transition period while State and local interests have opportunity to resolve financial and legal problems associated therewith.

I. Improved coordination and programing

Much has been said and written about the need for coordination of water resources development. Certainly, it is an important consideration for the absence of proper coordination can lead to social discord and controversy and least of all to progress. Several major steps which the Congress might take are discussed below for it is hoped that out of the current Senate study of water needs and capabilities there will come the ingredients which will lead to improved efficiency in the development of the Nation's water resources.

Federal development revolves around specific project investigations, and hence adequate coordination between Federal agencies and between State and Federal offices is difficult to achieve unless (*a*) funds for a given project area are made available to all Federal agencies at the same time and (*b*) there is sufficient advance scheduling of project investigation and construction funds at the Federal level to allow proper adjustment in schedules of the affected non-Federal interests. Generally speaking, fiscal programing necessary to fulfill either of the foregoing objectives has not been forthcoming in the past. Nonetheless, a practical example of the need for and desirability of advanced scheduling from the non-Federal viewpoint can be illustrated by a situation where a city or some other non-Federal entity wishes to cooperate with the Federal Government in the construction of a reservoir project. Uncertainty as to when the proposed Federal funds may become available does not lead to progress or to public understanding. Similar considerations are posed for many State, local, and/or private groups facing relocation problems associated with Federal project development. Conceivably, congressional establishment of a firm planning and construction schedule 3 years in advance, coupled with an annual reappraisal of a tentative schedule extending a minimum of 10 years in the future, would help this overall problem of program coordination as it relates to both interagency and intergovernmental relations.

Undoubtedly, congressional action which would clarify Federal and non-Federal responsibilities and prerogatives in the various phases of water resources development would be most helpful. Until there is a firm establishment of Federal policy, it is improbable that 50 separate States and their many local entities will uniformly arrive at programs equally compatible with Federal operations. As pointed out by many water policy reports, there needs to be a clear congressional expression as to whether State water laws are to be recognized by the Federal Government, what functions of project development are to be deemed reimbursable, how project costs are to be allocated between functions, etc. Most important, however, is the need for congressional designation of the guidelines to be used in determining the relative economic worth and/or social urgency of a given project. The possible needs in Kansas alone, as cited herein, would indicate that some selectivity is desirable because (1) the overall task is tremendous and (2) the concept that every possible development should be undertaken immediately is fallacious. Certainly, if as a result of the Senate committee's study there evolves a congressional expression of the degree to which the Federal Government would expect to meet at any given date the many needs theoretically eligible for consideration under existing legislation, it would be possible to cast the non-Federal responsibilities in a far better perspective than is now possible.

KENTUCKY

KENTUCKY WATER RESOURCES STUDY COMMISSION,
DEPARTMENT OF CONSERVATION,
DIVISION OF FLOOD CONTROL AND WATER USAGE,
Frankfort, Ky., July 29, 1959.

HON. ROBERT S. KERR,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: Your letter of June 23, 1959, to Gov. A. B. Chandler, has been referred to this commission.

Enclosed is the information requested with a "draft copy" of the Kentucky water resources study. This study will be published in September of this year, at which time we will send you a final copy for your files.

If there is any more information needed from the Commonwealth of Kentucky, please let me know.

Sincerely yours,

WILLIAM M. LYON, *Executive Secretary.*

COMMONWEALTH OF KENTUCKY,
DEPARTMENT OF CONSERVATION,
DIVISION OF FLOOD CONTROL AND WATER USAGE,
Frankfort, Ky., February 8, 1960.

Senator ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate Office Building, Washington, D.C.

DEAR SENATOR KERR: I have been informed by Mr. Theodore M. Schad that you have received no statement on Kentucky's water resources and problems. As February 10 is the deadline I have hurriedly drafted the following. If at a later date you want additional information, please request it.

This division has recently published the findings of the Kentucky Water Resources Study Commission. Under separate cover I am sending you an ample supply of these reports, as requested in your letter of August 3, 1959, this report contains all of the factual data concerning our water resources in Kentucky.

Our most serious problem is the unequal distribution of 46 inches of average annual rainfall over the 40,400 square miles that is Kentuckys' area. Ninety seven percent of this tremendous volume of water is carried into the Ohio River through 11,000 miles of streams, the largest of which are the Cumberland, Tennessee, Big Sandy, Kentucky, Salt, Green, and Licking Rivers, and 3 percent goes directly into the Mississippi River. It is easy to understand why we suffer each and every year serious damages from floods ranging in intensity from the largest flood of record, that of 1937 which affected the entire State, to the comparative small but damaging floods that occur each year in varying sections. It is hard to understand that while floods are harassing some sections of Kentucky, other sections simultaneously are suffering from periodic, but serious and damaging droughts. It is harder to understand that sometime during the year the volume of water in each of the above streams varies from a maximum of minor to severe flood stages to a minimum flow inadequate, or threatening, for municipal and industrial uses.

Finally, realizing the seriousness of this situation the legislature in 1948 created this division of State government, charging it with the responsibility of developing a flood control and water conservation program for Kentucky, and of cooperating with other State and Federal agencies in its prosecution.

The cooperation we have had from Congress, the Corps of Engineers and the Soil Conservation Service has been excellent. Cooperating with this division the Corps of Engineers has studied and recommended programs, which have been authorized by Congress, for each of our rivers for flood control, power, navigation, channel improvement and other remedial measures, and the Soil Conservation Service under Public Law 566 has planned small watershed projects that are valuable not only to our agricultural interests but to the life expectancy, maintenance, and operation of the larger projects of the Corps of Engineers. However, the overall planning of water-development projects has uncovered the need for additional authority to be given by Congress to both the Corps of Engineers and Soil Conservation Service.

No project where a damsite is used can be considered properly planned unless every possible present and future use of that site has been included. A municipality should not be allowed to build a dam for municipal water only. Agricultural, industrial, and flood control needs should be incorporated, and the same should apply to every dam built regardless of the principal need. This unfortunately has not been done to date. For instance the Corps of Engineers have built and are planning so-called multipurpose dams without providing for storage space for anticipated future needs. Another instance, modern navigation facilities have been provided for the first 103 miles up Green River, and recent developments justify the extension of this 9-foot channel some 70 miles further to the city of Bowling Green. Every indication is that industry, requiring large amounts of water, would move into this area, yet no industrial water has been provided in the flood-control dams in the watershed. The cost of this additional storage is small compared to the overall cost of the project when included in the original construction, but is prohibitive in most instances when added after a structure is completed. The Federal Government should include and pay for this storage on every dam built where the need could develop in the foreseeable future.

Kentucky is developing a program of assistance to small towns, industry, agriculture, and other agencies in the building of small dams. Investigation has shown that neither the Soil Conservation Service, nor any other Federal agency, has the authority to participate in these structures. The Soil Conservation Service should have the authority and funds to install the needed flood-control storage and facilities in these structures so that if and when a watershed program under Public Law 566 is set up in this area the flood-control features will have already been installed in these damsites and the program will not have suffered. Good damsites even in Kentucky are not plentiful and should be utilized for every purpose.

The program that has been set up in the Farm and Home Administration in the Department of Agriculture for lending money to local organizations cooperating with Soil Conservation Service under Public Law 566 should be liberalized. So far in Kentucky no loans have been made. The watershed program is moving rather slowly here, but could be greatly accelerated if these loans were easier to obtain.

Every indication is that before 1980 the industry of the Nation will be forced to expand to keep abreast of the modern demands of an ever-increasing population, and that water more than any other one requirement will determine the degree and the direction of that expansion. Kentucky intends to cooperate to the fullest with Congress and the Federal agencies concerned and to push for the ultimate development of our water resources for with our water resources properly developed, Kentucky can offer industry more than any other section of the Nation. Location, timber, coal transportation (both water, air and rail), electrical energy, industrial sites and local labor, are all assets which Kentucky possess.

I am sorry that I did not have time to prepare a more comprehensive statement, but sincerely trust that the select committee can recommend that Congress pursue an accelerated program in cooperation with the States in the development of our water resources in Kentucky and the Nation.

With best wishes, I am,

Sincerely yours,

STEPHEN A. WAKEFIELD, *Director.*

LOUISIANA

State of Louisiana,
Department of Public Works,
Baton Rouge, January 12, 1960.

Mr. Theodore M. Schad,
Staff Director, Senate Select Committee on National Water Resources,
New Senate Office Building, Washington, D.C.

Dear Mr. Schad: Senator Kerr's letter of June 23, 1959, to the Governor of Louisiana, requesting a statement concerning Louisiana's present and anticipated water problems, was passed on to this department since we are the agency responsible for the water resources development program in this State. Two copies of our statement furnishing the information requested is enclosed for use of the committee.

I am sorry to be so late in submitting this information; however, as explained to you previously, the Governor's office did not refer it to us until a rather late date. If we can be of any further service to the committee with reference to problems in this area, we shall be glad to furnish any information needed.

Sincerely yours,

Calvin T. Watts, *Assistant Director.*

A Brief Statement Concerning Louisiana's Present and Anticipated Water Problems in Response to the Request of Select Committee on National Water Resources of the U.S. Senate

1. ORGANIZATION FOR WATER RESOURCE DEVELOPMENT

The department of public works is the State agency responsible for development of Louisiana's water resources. It was created in 1942 by combining into one organization all of the functions of the board of State engineers, the flood control and water conservation commission, the flowage rights commission, the State planning commission, and several other minor boards and commissions.

The duties of the department include all of the administrative functions of the State in relation to planning, design, survey, construction, operation, maintenance and repair of public buildings, levees, canals, dams, locks, spillways, reservoirs, drainage systems, irrigation systems, landing fields and other aeronautical facilities, State planning, inland navigation projects, flood control and river improvement programs, public housing projects, and other public works.

Most of the department's work is concerned with water, for water has been and will continue to be the most important factor in the development of Louisiana.

Louisiana stands alone among all the States in the magnitude and variety of its water problems. Foremost among these problems is that of flood control, for all of the drainage from 41 percent of the United States passes through the State and reaches the sea within its borders. Heavy rainfall on the extensive areas of low, flat lands creates many local drainage problems, and periodic droughts bring severe water deficiencies, particularly in the rice-growing sections dependent upon irrigation. Added to these are the problems of beach erosion, salt water intrusion into the coastal streams, stream pollution, and the development and maintenance of navigable waterways. All of these problems come under the jurisdiction of the department of public works for solution and remedial action.

2. WATER RESOURCE DEVELOPMENT IN LOUISIANA

A. Flood control

The welfare and prosperity of Louisiana is dependent upon flood control. This basic fact has dictated State water policy in the past and will continue to do so in the future.

Over 16,000 square miles, nearly one-third of the State, lies in the great river valleys which under natural conditions are directly exposed to the threat of flooding from the Mississippi, Atchafalaya, Red, and Ouachita Rivers as these streams convey the drainage from 31 States and 2 Canadian Provinces through Louisiana to the Gulf of Mexico. About 2,270,000 people, or 72 percent of the population, live in this area, which also includes about two-thirds of the State's industry.

In earlier times, Louisiana was concerned almost entirely with disposal of storm and floodwaters. With flood control on a dependable basis, however, public and private developments of impressive proportions have been made possible, so that today other types of water resource problems are rapidly coming into prominence. In many instances the newer problems have resulted directly from the application of flood control measures.

Louisiana began work on its water problems in 1717 when Bienville built the first levee at New Orleans. Until 1852, when the first levee district was formed, this work was the responsibility of the riparian landowners. The modern levee districts date back to 1886, and since that time responsibility for major flood control has gradually passed to the State and Federal Governments. Twenty-two levee districts are now functioning with flood control.

Since 1886, the State of Louisiana and the levee districts have spent over $300 million on flood control, with annual expenditures for the purpose now ranging from $12 to $15 million. During the same period Federal expenditures have amounted to about $400 million. Most of the Federal work has been accomplished over the past 30 years under the Flood Control Act of 1928, as amended. Benefits accruing to Louisiana from the Federal program to date amount to $2 billion, which is also an indication of the losses which the State would have suffered without flood control.

B. Drainage

Historically, drainage has ranked next in importance to flood control in Louisiana. As a result of studies to determine what should be done to improve and extend drainage throughout the State, the department evolved and sponsored the parish countywide drainage programs which are now in effect. Earlier drainage projects were usually haphazardly performed by small districts with limited resources and without coordination or adequate engineering.

Under the present program the Federal Government, with the State contributing part of the cost, improves the major outfall channels in a drainage basin; the State and parishes jointly improve the lesser streams and construct the main laterals; and the drainage of individual farms is done by the farmers with engineering and financial assistance from the U.S. Soil Conservation Service. All channels other than farm ditches and Federal projects are maintained by the parishes.

This arrangement has proven very satisfactory, and 46 of the 64 parishes and 10 of the 22 levee districts have participated in the program. Over 200 million cubic yards of earth have been removed in the course of the work excluding the major streams improved by the Corps of Engineers and the farm drainage by the Soil Conservation Service. Expenditures by the department for drainage projects now range from $2 to $3 million annually.

C. Navigation

The improvement and construction of navigable waterways is another water resource activity in which Louisiana has been engaged from earliest times. Waterborne commerce, both domestic and foreign, plays an essential part in the economic life of the State.

Louisiana has about 7,500 miles of navigable streams—far more than any other State. Over 2,200 miles are maintained as major arteries of commerce, and three of the largest ports in the United States are situated on these streams—the port cities of Lake Charles, New Orleans, and Baton Rouge. Most of the smaller waterways traverse the coastal marshes and provide the only means of developing the oil, gas, and sulfur deposits of an otherwise inaccessible area.

Most of the channels leading into the gulf were formerly adequate for the small fishing craft which were the principal users, but are now quite inadequate for the volume and type of craft which operate in this area.

The menhaden fishing industry, using large, deep-draft vessels, has become established at several points along the coast. The drilling and servicing of the offshore oil and gas fields, and the laying of marine pipelines, all requiring the use of large craft, are other recent developments which emphasize the almost complete inadequacy of existing waterways into the gulf.

It is the established policy of the department to improve and extend adequate navigation facilities to all areas where feasible. In carrying out this policy, the department works closely with the Corps of Engineers, the Federal agency responsible for navigation improvements. On its own account, the Department has built two locks on the Mississippi River which it operates, has constructed many miles of navigable channels, assisted local harbor and terminal districts in the development of port facilities, and makes feasibility and traffic studies for the various port commissions.

D. Water supply

While Louisiana's water supply is probably the most abundant of any State in the Nation, the problems associated with distribution, pollution, and periodic droughts are equally as great. Louisiana uses more water than any other Southern State except Texas—we have some 600,000 acres under irrigation—more than any State outside of the arid West.

The principal problems concern distribution of existing water supplies both with respect to geography and time. In one season we have too much, in another too little; an abundance in one area, a shortage somewhere else.

All of the coastal streams are subject to salt-water intrusion—a very serious matter in that portion of the State where fresh-water requirements are greatest, and where in large areas there is no fresh ground water available.

Ground-water levels have also declined to an alarming extent in the rice irrigating and industrial areas of southwest Louisiana. About 250,000 of the 600,000 irrigated acres depend on wells for water. At some points, notably on the lower Vermilion River the decline in water levels is accompanied by the entrance of salt water in the aquifer.

The Department is constantly engaged in studying all of these problems. In cooperation with the U.S. Geological Survey the State has been gathering basic information on ground and surface water supplies since 1937. The Department is now spending $250,000 annually in matching funds for this purpose. In addition, the Department makes many special studies of local and regional water problems, such as the study of southwest Louisiana water supply problems at a cost of $150,000; and the model study of means to control the salinity problem in Vermilion Bay at a cost of $250,000.

The Department has recently completed two projects distributing the waters of the Mississippi River, and several more such diversions are now under study. Flow in Bayou Lafourche, long stagnant as a result of flood-control work, was reestablished at a cost of $1,500,000 by means of a 400 cubic feet per second pumping plant, making it possible for communities as far as 100 miles away to construct modern water supply facilities. Fish and wildlife interests have been benefited by the Bayou Lamoque control structure below New Orleans which permits diversions of fresh water into the oysterbeds in the coastal bays and lagoons.

Most of Louisiana's water supply and stream pollution problems (principally salt-water intrusion) have come into prominence in comparatively recent times. Most of these problems are found in the coastal areas which contain most of the State's mineral wealth. As a matter of record, 22 percent of the Nation's natural gas reserves, 16 percent of the petroleum, and about half of the sulfur reserves are found in coastal Louisiana.

3. ANTICIPATED WATER PROBLEMS

Louisiana's water problems of the future will continue to be those of the past, except that some, such as water supply, will become more prominent. In order of importance, the Department expects that water resource development activities by 1980 will be directed toward—

1. Flood control and drainage.
2. Water supply.

3. Alleviation of salt-water intrusion.
4. Navigation.
5. Stream pollution abatement.
6. Recreational and fish and wildlife uses.

A. Flood control and drainage

Insofar as major flood control is concerned, what Louisiana needs most today is to complete the presently authorized Federal program as rapidly as possible, modifying it to include:

(*a*) Channel and bank stabilization of the Mississippi River from Baton Rouge to the Gulf of Mexico, and on Red River from Arkansas to the Mississippi.

(*b*) Increased authorization for channel and bank stabilization of Mississippi River, Cape Girardeau to Baton Rouge, La.

(*c*) Measures increasing low waterflow so that prospective demands of agriculture and industry can be met without creating or aggravating salt-water intrusion problems on the lower reaches of the Mississippi and Atchafalaya Rivers.

(*d*) Extension of levee protection to additional areas, Red River backwater area.

(*e*) Atchafalaya River and Floodway, increase in authorized project for levees, main channel dredging, and intercepted drainage.

Such a program would meet our greatest flood-control needs and help to solve other problems as well. However, it should be realized that the interests and values dependent on flood-control measures for prosperity and even for existence are already so vast, and with the protection now being afforded will probably so enlarge that increasing factors of safety will be demanded as time goes on. The present flood-control system affords only the bare essentials of protection. It was thrown up as rapidly as resources permitted over an extremely extended front to meet a grave emergency. Now that the emergency aspects have been met, the job in the immediate future is to strengthen and consolidate the entire system, and to increase present margins of safety.

B. Water supply

Total rural, municipal, industrial, and agricultural use of water in Louisiana amounts to 5,400 million gallons per day and is expected to increase to 7,500 million gallons per day by 1980. Twenty-five percent of the water used is consumed—that is, it is not returned to the stream.

The greatest increase in water usage is expected to occur in the southern part of the State where ground and surface water problems are already of large proportions. Because of the flatness of the land, there is little opportunity for storage reservoirs, so deficiencies must be supplied by diversions from the Mississippi, Red and Atchafalaya Rivers, increasing the low flow of these streams by upstream reservoirs, prevention of salt water intrusion, and perhaps pollution control in the upper reaches of the interstate streams.

Some of the problems have been created by construction of flood control works—structures which protect the State against sudden descent of floodwaters originating outside Louisiana. For example, one of the large lakes in the Atchafalaya Basin is slowly being lost as a result of the flood control program. In 1934 Grand Lake had an area of 104 square miles—today it is only half as large due to sedimentation, and it will probably disappear completely in advance of 1980. This lake was once an important source of municipal supplies in an area of very limited ground-water resources. There are many other instances where levees have intercepted distributaries of the Mississippi and Atchafalaya Rivers, producing stagnation and cutting off fresh water supplies of heavily populated areas.

The decline of ground water levels in the industrial and rice irrigating areas will have to be arrested, either by recharging the aquifers or by increased diversion of surface waters to these areas, or both.

Although Louisiana has no established legal policy with respect to the use of water, questions concerning water rights which do not involve Federal or interstate interests should remain subject to State control. Historically, most disputes in Louisiana arising from water problems have centered around the rights and duties associated with drainage and flood control.

C. Navigation

Louisiana, at the mouth of the mighty Mississippi River, is the gateway to Latin and South America. Tremendous growth over the next 20 years is expected to occur in the underdeveloped nations to the south, with a concurrent increase in trade with the United States, principally through Louisiana and gulf coast ports.

The trend toward larger, deeper draft tankers and ore carriers is well established—a trend which is already having its impact on Louisiana's navigation system and port facilities, since most of its industry is based upon petroleum and nonferrous ores.

Industrial development will most likely occur on the navigable waterways, but there will be a shortage of deep water industrial sites. New channels will have to be constructed and the Atchafalaya River opened to deep water navigation. New locks and salt water control structures will have to be built, and the Mississippi and Calcasieu Rivers will have to be deepened to accommodate the larger vessels that are coming into use. The inland waterways will also have to be enlarged to meet the requirements of the larger, more efficient equipment and tows that are being operated today. Most of Louisiana's navigational facilities will become inadequate within the next 20 years unless improvements keep pace with economic growth.

D. Pollution

Because of its extreme downstream location, Louisiana is more in the position of being offended than of being the offender in the matter of stream pollution, and the State will always be vulnerable to harmful wastes originating in the upstream States of the Mississippi Basin.

Pollution from out-of-State sources is already a serious problem in some localities at this time and is certain to increase with continued growth of the lower Mississippi valley. Reasonable antipollution measures should be adopted and enforced through the medium of interstate compacts.

Decisions with regard to regulation of waste discharges in the entire Mississippi Basin should be examined in terms of maximum beneficial use of the streams. Studies of each section of the principal streams should be undertaken with this end in view—to determine first the nature and degree of pollution, if any; the most important uses of the stream in the particular section under examination; and the most economical means of relieving the situation.

Some degree of pollution will have to be tolerated in the future, particularly where annual costs of corrective works or measures exceed damages attributable to waste discharges. No one benefits from unnecessary restriction of waste discharge, and a pollution-control program that is practicable, reasonable, and rational should be developed.

With respect to the main stem Mississippi River, maintenance of the minimum flow necessary to secure the authorized 12-foot navigation project between Cairo, Ill., and Baton Rouge will tend to further alleviate pollution during the critical low water period and prevent salt water intrusion up to New Orleans.

Louisiana's most serious pollution problems are due to natural causes—the intrusion of saline waters from the Gulf of Mexico into the coastal streams and contamination of runoff from highly mineralized soils, such as occurs in the Red River Basin.

E. Recreation

Louisiana's mild climate, its abundance of fish and wildlife, it beaches, lakes, and forests, offer wonderful opportunities for recreational development. There are many recreational lakes which will have to be built and many existing ones which will have to be improved for public use over the next few years to accommodate the growing population and the trend toward a shorter workweek affording more time for leisure. Most such lakes in Louisiana provide other benefits as well.

Recreational beaches, which could also afford protection against hurricane tides, must be developed, particularly on Lake Pontchartrain and Lake Palourde, near densely populated areas Coastal beaches should also be developed and preserved at many other locations.

F. Wildlife and Fisheries

Some of our streams have become stagnant and polluted as a result of flood control measures such as levees, diversions, etc. Fish and wildlife have been adversely affected by the levees which prevent annual overflow of fresh water into the swamps and bays along the lower Mississippi. The resulting problems should be corrected by diversions at suitable locations, otherwise the fish, oyster, and fur industries will continue to decline.

Public works projects which of necessity must accompany the projected economic growth of Louisiana are likely to conflict with fish and wildlife interests. Navigation, drainage, and reclamation projects will become more numerous in the coastal areas, tending to change the ecology of the entire region. Ultimately the questions of how much economic expansion can be tolerated and where it should occur will have to be answered, otherwise waterfowl and other forms of wildlife and fish will have to give way to the changes which will result from exploitation of the marshes and offshore areas for oil, natural gas, sulfur, and other minerals.

MAINE

State of Maine,
Office of the Governor,
Augusta, October 1, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: I have had prepared, and reviewed, a summary statement of existing conditions and projections for future demands on water in the State of Maine and two copies are enclosed.

We were unable to meet your deadline of October 1 but hope that the report will not be too late.

With my kindest regards, I am

Sincerely,

Clinton A. Clauson, *Governor.*

The Maine Water Resource—Current Supply and Utilization and Future Requirements

Introduction

In preparing this statement for the Senate Select Committee on National Water Resources, it became evident that there are some lacks in quantitative data on the basic resource itself. Nonetheless, we count ourselves fortunate in that we in the northeastern area of the United States do have at our disposal a basic study on water and related land resources which is second to none, that is the New England-New York Interagency Commission report of June 30, 1954. In addition to this the Northeastern Resource Committee formed by the New England Governors' Conference has sought to continue the NENYIAC and update, on a continuous basis, the data contained therein.

Water resources available in Maine

The water resources of Maine are bountiful in comparison with those of the majority of our sister States. The average annual precipitation is 40.2 inches, ranging from about 50 inches on the higher mountains to less than 35 inches in a small area in the northeastern section. Over 10 inches of this total falls as snow and much of it is temporarily held in storage on the ground during the winter months. Yearly runoff averages about 21 inches over the State's area of 33,040 square miles indicating that about 1,612 billion cubic feet (37 million acre-feet) of water is available each year for initial use.

Six major river systems and many smaller coastal streams provide surface drainage for the State. Storage reservoirs in the six major river systems have a usable capacity of about 160 billion cubic feet. Over 2,000 other lakes and ponds, some in the natural state and others with low dams, provide a considerable, but unknown, amount of additional storage of surface water and areas for recreational activity. It should be here noted that the coastal areas and the offshore islands do have some problems of fresh water supply.

The amount of ground water available in the State is unknown. However, preliminary investigations indicate a substantial quantity may be available in areas covered by glacial deposits, particularly in the southwestern section of the State. The area in northern Maine underlain by limestone is also believed to contain a considerable amount of usable ground water. Little ground water is available in bedrock areas.

Water quality is generally good to excellent. With the exception of sections of Aroostook County the waters of the State are soft and generally low in suspended material and mineral content and, except for small localized areas, are suitable for domestic water supply, agricultural, recreational, and industrial use. Some of the localized quality problems include high iron or chloride content, corrosiveness, radioactivity, and pollution. Excessive pollution is generally restricted to the lower sections of the major rivers.

Withdrawal and use of water

Little data on withdrawal and use of water is collected or analyzed by State agencies. Circular 398 of the U.S. Geological Survey entitled, "Estimated Use of Water in the United States, 1955" contains the best available summary of water withdrawal and use in the State. Nearly 200 times as much water is used in the production of power as by all other uses, but much of this water is reused many times. Presently installed wheel capacity of waterpower plants in Maine is over 800,000 horsepower. An additional 600,000 horsepower, based on 50 percent flow duration, is estimated to be available but undeveloped due to location, size, or other conditions which make current development unfeasible. Water used in the installed plants is estimated to be about 100 billion gallons per day. Public water supplies and rural domestic use are estimated to use about 100 million gallons per day. Self-supplied water for industrial use is about 500 million gallons per day. A little water is used for irrigation in Maine but the quantity is negligible, probably not over 2 million gallons per day. Ground water furnishes about 25 million gallons per day of these totals. Transportation of forest products, primarily pulpwood, is a major use of many streams. Little navigation, except by canoe, is done on the streams above tidewater but accessible lakes are used by innumerable pleasure craft. Sport fishing is another form of recreation which uses nearly all the surface waters of the State.

Maine law concerning use of water follows the riparian rights doctrine but consumptive use of surface water beyond a reasonable amount is prohibited. No specific law covering use of ground water has been enacted. Great ponds, covering over 10 acres in their natural state, are held in trust for the people by the State and are generally open to public use for recreation provided public access is available.

Fundamental problems

The problems of water resource in Maine are principally long range in nature. In view of the current adequacies of surface waters and apparent adequacy of ground waters to meet the normal day-to-day demands of the consumer, there is little urgency in terms of resource problems; however, certain facets of the resource do pose questions for the future. Perhaps the foremost concern is the lack of sufficient data, both in terms of quality (physical and chemical) and quantity of the resource. This is particularly true of ground-water resources in the State. Without such data it is certainly difficult, and in fact almost impossible to assure the most efficient and equitable use or uses of the resource.

A second problem might well be stated as the need to educate water users, from the family consumer to the large industrial and power user, as to the need for multiple use of the water resource and the most equitable means of obtaining an ideal solution among competitors for that resource. In relation thereto such education must also concern itself with the management of other related natural resources, such as land (farm practices, irrigation, erosion control); the forest resource (proper cutting to maintain control of the land and flowage), etc. As an example of the need for such education we might well cite the dilution of pollutants in which a problem exists because of the peaking of flows necessary to power production; maintenance of minimum levels in streams and ponds for the purposes of fisheries propagation; abrupt drawdowns causing scouring of spawning areas. All problems like these must be met with education—not only of the current users but of the public in its entirety.

Such education must logically proceed to our third problem which is the revision of the existent laws relating to the resource. The present body of Maine law affords no rights, either explicit or implicit, except to public water supply, power, and log driving. In fact, consumptive use of streamflowage is not permitted for the extant doctrine provides that, while flowage may be utilized, it must be returned to the source stream essentially the same in quality and quantity. These laws must be changed as necessary to acknowledge the rights and needs of all users.

Ground-water problems

No current ground-water problems of appreciable magnitude exist in Maine. The State is not presently beset with the multiplicity of problems that may plague other parts of the country such as falling water levels, interference in the flow of streams because of heavy pumpage from wells, or the deterioration in quality of ground water by the infiltration of water of undesirable quality such as sea water or oilfield brines.

However, large supplies of ground water—enough for municipalities or industries—are not everywhere available, and the principal problem is one of locating areas where large supplies of usable ground water exist. In general, it is known that the largest supplies occur in unconsolidated deposits of sand and gravel of glacial origin. Moderate, though hard, supplies of water can be obtained from the limestone formations of northern Maine, but generally only small yields can be obtained from wells drilled in other bedrock types. Before ground water can be utilized to its greatest extent the location and limits of the principal water-bearing formations must be delineated, and the amount and chemical quality of the water contained therein and the rate at which it can be produced from wells or springs must be determined.

Though ground water in Maine is generally of good quality for most uses, in places it is excessively hard, is corrosive, or contains excessive amounts of such constituents as iron, chloride, nitrate, or radioactive minerals, and, therefore, cannot be used for certain purposes.

Water use for pollution abatement

Maine is fortunate in the quantity of precipitation it receives, but as is often the case, much of the runoff occurs where maximum advantage cannot be realized from it. A considerable area of the State is semiwilderness and access by the general public is difficult and limited, a fact which must be considered when evaluating it. In the populated areas, pollution varies from moderate in less-developed sections to heavy in waters adjacent to areas of more intense development. Much of the total runoff of the latter areas is hard pressed to assimilate the pollutional load it receives.

The heading "Water Use for Pollution Abatement" is actually a rather narrow field as applied to conditions in our area, being in fact limited to firming up of streams by storage to achieve more advantageous dilution. Unless storage is used with object of lessening the effects of waste stabilization in view, it is difficult to justify assigning any benefit value for this purpose to it. While it is true that the use of storage to make the flow on a Wednesday during a dry spell in August more nearly equal to the mean annual discharge would benefit pollution conditions on that day, storage for hydropower purposes is not always used to firm up a flow 24 hours daily throughout the year. Such things as load and plant factors enter the picture.

Population projections

Using some of the intercensal estimates published by the U.S. Department of Commerce, Bureau of the Census, in which a mid-1958 population for the State of Maine was estimated at 952,000; the 1970 estimate 1.088 million and the 1975 estimate 1.180 million, we have made a graphic projection of these data through the years 1980 and 1990. It is certain that these estimates will have to be revised when the 1960 census becomes available; however, with data currently available these estimates show a population in 1980 of 1¼ million in the State of Maine.

Applying to that figure of 1¼ million persons, the per capita consumption of water from municipal sources as shown in Bulletin 398 of 148 gallons per day, we obtain a per capita need in 1980 of approximately 185 million gallons per day. To this we must add a factor of nonresident seasonal population which is estimated at least to be an additional one-half of the domestic requirements bringing the total requirement to 277 million gallons per day. The 148-gallon-per-day figure is probably in the order of an overstatement as the current figure used for projection purposes to estimate personal water requirements is 100 gallons per day.

Municipal water use

In the State of Maine there are some 161 public water systems ranging in size from the Portland Water District supplying a population of 145,000 persons, to small seasonal supplies serving less than 100 persons. Inasmuch as all water utilities in the State are subject to the jurisdiction of the Maine Public Utilities Commission, there are available at the commission offices annual reports of most of these utilities. Shown in the respective reports is a monthly record of total water delivered to the mains of the water systems. No breakdown or estimate of water used for domestic or industrial purposes is available from the reports.

In determining the water used for municipal purposes at the present time, the annual reports of nine of the larger water utilities were selected.

These nine water systems supply 39.6 percent of the customers served by public water systems, with an average use of about 35 million gallons per day.

Accordingly, it is estimated that the total average municipal water requirements approximates 88.5 million gallons per day, of which some 11 million gallons per day is obtained from groundwater supplies. By 1980 it is estimated that total municipal water consumption will approximate 145 million gallons per day. This is probably somewhat less than would be expected on a national average, due partially to the fact that full metering of water service in Maine has not been felt necessary in the past years. At the present time however, metering programs are being initiated by several water utilities.

Municipal water use is, of course, but a small portion of the total water requirements, and with the many excellent sources available for public water supplies, no major overall problems are foreseen. Individual problems can be expected however, and high construction costs for water supply facilities will be foremost.

Along the "rocky coast of Maine," especially in the island communities, there will be problems which can be best alleviated by desalinization, when economically feasible.

Agricultural use of water

How much water is needed for agriculture? There is a dairy industry in Maine. A holstein cow in full production during the summer months needs about 30 gallons of water per day. Maine has over 200,000 dairy cattle but they aren't all holsteins and they aren't all in full production, cutting the need to 20 gallons per cow per day, the total requirement is 4 million gallons per day.

The broiler industry approximates 60 million birds per year; about 15 million broilers housed at any one time plus about 4 million other chickens, or roughly 20 million head of all kinds, at 5 gallon per 100 birds equal 1 million gallons per day. Then add beef cattle, sheep and hogs, horses, and miscellaneous animals for another 1 million gallons a day.

What does it take to produce the crops we grow on our farms in Maine? With 1,500,000 acres in crops, about 6 million gallons of water per day is needed to get maximum growth.

Maine's average rainfall is slightly over 40 inches per year, well distributed on the average. That is to say, about half of it occurs during the growing season from April 15 to October 15, or 20 inches of rainfall which will not quite provide that 6 million gallons per day for growing crops.

Irrigation as an agricultural measure in Maine is in the formative stages. Farmers have been experimenting with irrigation for practically all the crops we grow in Maine. And in some of the recent dry years some farmers have been very disappointed in the results they have obtained, because it's too late to begin to apply water when a crop has reached the wilting stage. When irrigation becomes an accepted practice in the humid areas of the East it has to be a part of the planned operations program of a farm.

Whether records indicate that in a 10-year period, 3 years will have insufficient rainfall during the growing season, 2 years will be slightly short, 2 years will be slightly on the wet side, and 3 years will be definitely wet years. Premising our requirements for irrigation water on the basis of a need at least every other year, then the question resolves itself into how much water may be needed. In an extremely dry year as much as 10 inches may be needed. This would be the maximum amount applied in any one year so if we intended or planned our agricultural water supply on the basis of meeting our total need for water during our driest years we would need 1 acre-foot of water for each acre of land to be irrigated.

Assuming we are going to keep a million and a half acres of land in crops then the need is for that many acre-feet of water or 1½ million times 325,851 gallons.

There are some fairly sizable areas of sandy, nearly level land in this State which could be used to produce food and fiber by proper fertilization and irrigation. Some of our more progressive blueberry growers are beginning to use irrigation to protect the plants from late frost in the spring and insure more uniform size and quality of berries. These are some of the foreseeable future needs for agricultural water in Maine. Any real development or progress in these areas will materially increase the need for agricultural water. At the present time there are about 250 irrigation systems in Maine capable of watering about 6,500 acres of land and let me say that there is plenty of water available for irrigation (subject to legal restrictions relative to cousumptive use of flowage).

The amounts of water needed for some of our common crops are:

A 200-barrel crop of potatoes needs about 20 inches of available water.

A 50-bushel per acre crop of corn about the same or slightly higher.

Grass crops need 20 to 22 inches of water per year.

Fruit trees need slightly more—up to 24 inches.

Forests and water

In the Maine economy no other natural resource except water itself is more important than the forest which currently takes up 16.8 million acres or 84 percent of the total land area in the State. Products dependent on the forestry resource such as lumber, pulp, paper, furniture, etc., account for almost 40 percent of the total value of manufactured products in the State. The U.S. Forest Service in joint cooperation with the State forestry department and private industry will release, by June 30, 1960, a complete comprehensive report to be known as the Maine Forest Inventory. It will contain data on volume of wood by species by county, economic values, and future trends of the overall forestry picture. This report will be integrated as part of the multiple land-use management picture of timber harvesting, wildlife management, recreation and water resource values.

The cycle of forest acreage is now on the upswing side. In 1920 there were 18.5 million acres in forest, the current figure is 16.8 million acres and the projected estimate for 1980 is better than 20 million acres in forest. Aside from the direct economic value of forest production there is the even more valuable protection that the forest cover furnishes to the watershed in terms of water retention, erosion prevention, etc. The natural storage afforded by such cover serves to maintain a balance between precipitation and surface flowage by the prevention of immediate runoff.

While we have no readily available data on the actual amount of water utilized by Maine forests—for maintenance of life and growth, we do know that approximately 30 percent of total precipitation in forested areas is intercepted and at least partially utilized by the tree cover. As an example of water requirements however, it has been demonstrated that nursery grown southern pine seedlings require approximately 1 inch of water per week for the first summer. It has been also stated that adequate forest growth requires approximately 25 inches of precipitation annually as a minimum—this does not however say that this precipitation is fully consumed but merely establishes a minimum criterion. Further, the altitude, humidity, and other factors affecting transpiration may alter these standards materially.

Water needs of industries (including atomic)

The study of industrial processing water in Maine manufacturing establishments was undertaken in the census of Maine manufactures, 1959. It consisted of a mail questionnaire asking (1) The volume of processing water used, and (2) The quality requirements. The results of this survey were published briefly in the census of Maine manufactures, 1957, DLI Bulletin 262 in appendix K. This analysis covered 60 percent of the manufacturing establishments in the State and some 48 percent of the total production value in that year. For the purposes of this report we have prorated the census data to the total production level of 1957 with an estimated processing water use in Maine manufacturing (principally self-supported, i.e., nonmunicipal) of 450 million gallons per day. Of this total approximately 79 percent indicated quality specifications of a very high order. It should be here noted that this projection from a 48 percent sample of production value to the total economy of Maine manufacturers has serious weaknesses. The most important being, that all industries do not have processing water requirements at the rates indicated by the survey respondents. Further notice, however, should be given to the fact that the question related only to processing requirements and not to those requirements relating to waste disposal, coolants, etc. The actual results of the study cited are shown in table below:

[Excerpt] from "Census of Maine Manufactures," 1957, appendix K]

TABLE K-1.—*Water use by selected industry*

	Coverage		Processing water used				
				No quality specified		Quality required	
	Number reporting	Value of product (millions)	None (number reporting)	Number reporting	Daily gallons (thousands)	Number reporting	Daily gallons (thousands)
Total	356	$654	216	65	45,425	75	170,365
Food	83	96	8	26	2,818	49	5,043
Textiles and apparel	39	82	17	13	1,878	9	4,304
Paper	20	298	5	4	38,000	11	158,210
Leather	23	55	18	3	506	2	2,700
Others	191	123	168	19	2,223	4	108

NOTE.—This study was based on processing water only and has no relation to water used for waste disposal per se. Of the 356 replies, 216 or 60.7 percent indicated no processing water used while 65 (18.3 percent) reported some 45 million gallons used daily with no quality requirements. The remaining 75 (21 percent) used water with strict quality specifications totaling 170 million gallons per day.

The parenthetical question in item II–D relative to atomic power may be answered within the framework of several somewhat nebulous premises. My own assumption would be, knowing that the current system of nuclear energy utilization is certainly not the most efficient that could be expected to develop within our technology, that such advances in technology would greatly lower the water requirements of nuclear utilization. It is true, however, that current systems do require tremendous volumes of water for steam production or other heat exchange. However, it is also true that there are at present no nuclear projects planned for Maine.

Electric energy

The consumption of electrical energy in Maine has been increasing at a rate of about 7 percent per annum during recent years. This has been due to the expanded use of new appliances as well as to customer growth. It has been estimated that the energy requirements for the Nation will increase some 3½ times between 1959 and 1975. Maine is not likely to enjoy as large an increase because of our climate which is too cool to require much air conditioning, and so cold as to make the heat pump noncompetitive with conventional heating. However, there will be some of this type load in Maine, but not as general as in other parts of the country. The major domestic and commercial load growth is expected to ge caused by such equipment. Further, Maine's industrial growth is not as great as some other parts of the country.

In view of the above, it would seem that the electrical energy requirements in Maine might about double during the next 20 years, and at that time be approximately 4,600 megawatt-hours. This additional power will be provided largely by conventional steam plants and the balance by new hydro, nuclear and imports. There have been two hydro developments mentioned recently as perhaps being economically possible in the near future. These are the high Errol Dam in New Hampshire and Rankin Rapids Dam on the St. John River. These would increase the use of water significantly. Water use for fuel-generated electric energy is relatively small when compared to hydro generation.

According to the U.S. Geological Survey Circular No. 398, the water use for electrical energy in Maine was nearly 100 billion gallons per day in 1955. It is expected that the increased use of water will be nowhere near in direct proportion to electric energy production because of the increased use of fuel generation. A reasonable figure for water use in electric energy production for 1980 is in the order of 125 billion gallons per day.

Navigation

There is little probability of increased commercial navigation on Maine waters. Rivers are not suitable for dredging for barge or shallow draft craft except in tidal areas. Little long lumber is driven on rivers now and quantity of pulpwood being driven is diminishing gradually due to truck transportation over temporary roads; however, should feasible means be developed to drive hardwood—the situation might well reverse itself. In the section below relating to water recreation some further consideration is given to pleasure craft use of streams and ponds.

Flood control

Flood control is not a serious problem on Maine rivers. Except for small localized areas, little major damage is caused by floods and the cost-benefit ratio of possible control projects is very high. The Corps of Engineers, U.S. Army, have studied several proposed projects in the State and their reports are available.

Water recreation

Generally speaking, the State park commission is more concerned with the quality of water available in 1980 than it is with quantity. We are at present at the beginning of a boom in private recreational boating and one of our most natural assets is our rivers and harbors. The degree to which people use these waterways will certainly be dependent upon the quality of the water—not only whether it may be dangerous from a health point of view due to human pollution, but maybe just from an obnoxious and offensive odor from human plus industrial waste.

We will also be concerned in 1980 that our present ocean beach areas have a quality of water that is safe for swimming, etc. Some of these waters are now borderline and could go either way.

In summary, Maine has a terrific potential in 1980 in the field of recreational pursuits involving fresh and salt water and we naturally must be very vitally concerned with any development which involves water quality.

Fish and wildlife

Dr. Edward A. Ackerman has pointed out that, "* * * by 1975 approximately three-fifths of the total population will be living in two regions containing only one-fifth of the land area of the Nation."[1] One of these regions is a "megalopolis" extending from Boston to Washington, and including Baltimore and Philadelphia. This vast mass of humanity is becoming increasingly mobile. Maine is only a few hours' drive from Boston or New York, only a little over a day's travel from Washington or Philadelphia.

Dr. Ackerman's anticipated spilling-over of this population of recreation-seekers into Maine appears to be well underway, as indicated by sales of nonresident hunting and fishing license sales over the past 20-year period. Should it continue, by 1980 we can expect to have an army of 233,000 resident hunters, 220,000 resident fishermen, 56,000 nonresident hunters and 128,000 nonresident fishermen. This represents increases of 154, 158, 215, and 166 percent in the above categories.

The demand for increasingly intensive management of our wildlife is nowhere more important than in our ducks and geese, where we have a resource which is exploited not only in Maine, but to the northward and southward. Maine is a major producer of thousands of ducks which nest in Maine, but migrate and spend their winter within reach of the "megalopolis" referred to above. Our water, in the form of marshes, must also provide feeding and resting spots for other thousands passing through the State each fall and spring in their migration.

Waterfowl marshes are being continuously lost by a combination of drainage, fillings, pollution, and just plain use by campers and recreationists. Preservation of suitable marsh habitat is of great concern to conservationists throughout the Nation. Major marshes are being put into State or Federal ownership, new ones are being created artificially, and means are being sought to get the most out of remaining acreages of marsh, much of it now of marginal quality. This calls for a management program which is both costly and time consuming.

A second wildlife resource in which water is necessary is in fur producing animals such as beaver, mink, muskrat, and otter. Here the future demand will depend on trends in fur garment styles. The same marsh which produces waterfowl is the home of the beaver, mink, muskrat or otter, hence factors harmful to ducks also have their effect on fur animals.

The threefold increase that can be predicted in resident and nonresident anglers will mean greater water use by fishermen. Our trout and salmon are limited by water quality and water use much more than are our warm-water game fishes. It is probable that much of this increase in fishing pressure will be on our warm-water fish populations. In Maine multiple use of our surface water resources is a must if the increase in anglers is taken care of by providing water to fish and fish to catch.

The inventory of our fish populations is a continuous process. By this knowledge we are able to know where fish are and whether or not they are suitable or desirable to our Maine anglers. These inventories also give us up-to-date information on the effect of other water uses on the desirable fish populations.

Trends in use of water for waste disposal

Since no records of pollution loads in the State's waterways exist, it is impossible to present trends based upon statistics. It can only be said that a continuation of increases in pollutional load, which more or less parallel the State's industrial and population growth, can be expected as a minimum condition and possibly as more desirable areas become saturated the tempo of growth will increase.

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[1] Ackerman Edward A. "*Planning Future Natural Resource Development in Maine.*" Paper presented at meeting of New England Resources Council, June 12, 1958, Colby College, Waterville, Maine.

It does not appear to be unthinkable to decrease these loads on our waterways by a substantial amount but to the present time the people of Maine have not been willing to accord the water resource equality with others, and are generally willing to assign any body of water the role of an unlimited waste carrier, irrespective of present use, condition, or possibly more important place in the economy of the region.

Some reclamation of waterways is underway in Maine where particularly obnoxious conditions existed, and some lessening of new pollutional burdens may have been effected, but at the present time the total load on our waterways based upon potential oxygen consumption does not show a desirable trend.

Conclusions

From data contained in the several sections, we arrive at a total demand for water in the order of 126 billion gallons per day. Of this, industrial needs are second only to power production which is generally nonconsumptive. Power needs are estimated at 125 billion gallons per day; industrial at 450 million gallons per day; domestic, 280 million gallons per day; and agricultural (except forestry), 12 million gallons per day. It should be noted that much of the flowage is used several times in its travel downstream and, further, that consumption or use statistics do not reflect the amount of such reuse.

With regard to the means of meeting future demands, it is apparent that existing supplies are well in excess to current and projected future requirements. Many of the specific techniques shown in part III of the general outline from the committee (particularly forestry and water-related land management practices as related to evapotranspiration) will be applied as feasible; however, the major direction in Maine will be toward reevaluation of multiple-use flowage and storage to the end that equitability among the several competitors will be attained.

T. T. Trott, Jr.,
Director of Research and Statistics,
Maine Department of Labor and Industry

(For the Maine Interagency Resources Committee: Roland H. Cobb, Department of Inland Fisheries and Game (Chairman); Richard J McMahon, Public Utilities Commission; Austin Wilkins, State Forest Service; Ronald W. Green, Department of Sea and Shore Fisheries; E. L. Newdick, Department of Agriculture; T. T. Trott, Jr., Department of Labor and Industry; Lawrence Stuart, State Park Commission; Edward Langlois, Maine Port Authority; Sulo J. Tani, Department of Economic Development; Raeburn MacDonald, Water Improvement Commission).

September 30, 1959.

MARYLAND

Executive Department,
Annapolis, Md., June 29, 1959.

Hon. Robert S. Kerr,
Chairman, Senate Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

Dear Senator Kerr: On June 24, I wrote to you in reply to your communication to me of June 23 relative to Senate Resolution 48 which establishes the Senate Select Committee on National Water Resources for the purpose of obtaining basic data on the Nation's water supply.

I referred this matter to Dr. Joseph T. Singewald, Jr., director of the State department of geology, mines, and water resources. Dr. Singewald has given this matter his immediate attention and has written to Mr. Russell H. McCain, my executive assistant, under date of June 26. With his letter of the 26th, Dr. Singewald attached a paper which he delivered at a meeting of the Interstate Commission on the Potomac River Basin which was held in Richmond, Va., on January 22, 1958. This paper is very complete and authentic and deals with Maryland water resources and the control Maryland exercises over the use thereof.

A copy of Dr. Singewald's letter of the 26th together with a copy of the above-referenced paper are enclosed herewith. I believe that these two documents will give you the information and data which you requested in your communication to me of June 23.

With kindest personal regards, I am,

Sincerely yours,

J. Millard Tawes, *Governor.*

Board of Natural Resources,
Department of Geology, Mines, and Water Resources,
Baltimore, Md., June 26, 1959.

Mr. Russell H. McCain,
Executive Assistant to the Governor,
Executive Department, Annapolis, Md.

Dear Mr. McCain: I have your letter of June 24 with enclosures of copies of letters of June 23 from Senator Kerr, chairman of the Senate Select Committee on National Water Resources, to Governor Tawes, and of June 24 from Governor Tawes to Senator Kerr, the general outline of proposed procedure of the committee, and of Senate Resolution 48, adopted April 20, 1959, establishing the committee.

Senator Kerr requests that the committee be furnished with a statement as to the water problems of Maryland, both present and anticipated, to arise between now and 1980 and a statement of views as to what should be done toward the solution of these problems.

An inventory of the water resources of Maryland has been the major activity of the department of geology, mines, and water resources since 1943. Intimately related to this investigation has been administration by the department of the control over the use and appropriation of the waters of the State provided for in the 1933 Water Resources Act.

As an ex officio member of the special commission to study the water resources problem in Maryland (1955) and of the legislative council committee on irrigation and water resources (1957) and through attendance at two conferences of representatives of the humid southeastern States under the auspices of the Council of State Governments, this question has been in the forefront of my experience and uppermost in my thinking for a number of years and especially actively so during the last 5 years.

A concise yet comprehensive summary of the conclusions based on this experience and thought was prepared in January 1958 for presentation at a water resources development panel under the auspices of the Interstate Commission on the Potomac River, a copy of which is enclosed. The only change or addition that I could make in this statement would be to expand it with detail. The quantitative aspects of the water resources of Maryland are presented in somewhat more detail in the enclosed copy of the 1955 report of the committee to study water resources which functioned as a committee of the 1955 special Maryland commission.

The 1933 Maryland Water Resources Act is unquestionably superior to the legislation in any other State. The primary reasons are that the law is the enactment of a policy and that a flexible application of the policy is placed under the administration of a competent impartial commission. The only new legislation desirable now or before 1980 is to remove the existing exemption of the use of water for supplemental crop irrigation, a use that was wholly unforeseen and unanticipated in 1933.

It results only in confusion and endless duplication of futile voluminous commission and committee reports to consider the problems of water resources on a national geographic basis. The problems can be successfully and satisfactorily solved only on the premises of the relation of rate of replenishment to rate of consumption, a relation that ranges over the wide ratio from a State like Maryland in which present consumption is only 6 percent of replenishment and in which even the most liberal estimates of population increase and per capita increase in consumption still have the predicted needs in 1980 exceeded many times by the rate of replenishment to the slender margin or deficiency now existing or predictable by 1980 in arid to semiarid regions of the United States.

No State has assembled as complete knowledge of the amount and availability of its water resources as Maryland. No State has more satisfactory legislation in the control and appropriation of its water resources than Maryland. Maryland is well taken care of in its water needs and water resources legislation to 1980 and beyond.

The promptness of this reply does not mean that it is not the product of long and careful thought but is possible only because of antecedent long and careful consideration of the subject. I will be glad to amplify any aspects of the subject that you may desire to have discussed in more detail.

Sincerely yours,

JOSEPH T. SINGEWALD, Jr., *Director.*

[Interstate Commission on the Potomac River Basin Water Resources Development Panel, Richmond, Va., January 22, 1958]

MARYLAND'S WATER RESOURCES AND MARYLAND'S CONTROL OVER THEIR USE

(By Joseph T. Singewald, Jr., director, department of geology, mines, and water resources)

MARYLAND'S WATER RESOURCES CONTROL

In 1933 Maryland asserted control over the appropriation or use of the surface and underground waters of the State "in order to conserve, protect, and utilize the water resources of the State in accordance with the best interests of the people of Maryland."

The act was administered by a water resources commission which in 1941 was merged into the existing department of geology, mines, and water resources.

The act requires a permit to appropriate or use water and a public hearing on applications for permits.

The authority granted the department in the exercise of the control reads:

> If the commission shall be of the opinion from all of the evidence before it that, in the pursuance of the policy of the State regarding its water resources herein declared, the plans of the applicant provide for the greatest practical utilization of the waters of the State and will promote the general public welfare, it shall grant the permit to appropriate or use the waters. But if the commission is of the opinion, from the evidence before it, that the proposed appropriation or use of State waters is wasteful or will be detrimental to the best public interest, the commission may reject such application or it may suggest such modifications as it deems sufficient to protect the public welfare. In granting any permit authorizing any use or appropriation of water, the commission may include in the grant thereof such conditions, terms, and reservations with

respect to the character, amount, means, and manner of such use as it may deem reasonably necessary to preserve the proper control in the State and to insure the safety and welfare of the people of Maryland.

Decisions of the commission may be appealed in the circuit court of the counties and carried to the court of appeals, assuring the administration of the act in accordance with the declared policy of the State.

The act provides further that it "shall not be construed to impair any riparian or other vested right." The act does not define the extent or the limitation of riparian rights.

The act exempts from control the appropriation or use of water for domestic and farming purposes. In Maryland, as in the other eastern humid States, in 1933 farming and domestic uses were coextensive with domestic use as recognized under riparian right; namely, uncontrolled use of water for the household, family farm animals, poultry, and other livestock, and the family garden and lawn. The use of water for crop irrigation in the eastern humid States was then wholly unforeseen. The recently introduced practice of crop irrigation has made an increasingly widening breach in the adequacy of the Maryland law.

MAGNITUDE OF MARYLAND'S WATER RESOURCES VERSUS WATER CONSUMPTION

Water is the only replenishable mineral resource. An insufficiency of water resources can exist only when and where the rate of consumption exceeds the rate of replenishment.

In 1943, the department of geology, mines, and water resources began a comprehensive inventory of the water resources of the State in cooperation with the U.S. Geological Survey. Many additional stream-gaging stations were installed to obtain statewide streamflow coverage with respect to geographic distribution, size of streams, and topographic and geologic features of drainage basins. A statewide net of observation wells was installed to measure seasonal fluctuations in ground-water levels and trends in ground-water levels affected by pumpage. Pumping tests have been conducted throughout the State to determine hydrologic properties of aquifers—their transmissibility and their storage. This systematic inventory has been made county by county. It has been completed in the Baltimore industrial area and in 22 of the 23 counties of the State. The results have been published covering the Baltimore area and 21 counties, leaving but 2 counties for which the results are not yet written up. The cost of these investigations has been in excess of $1,500,000, which was been provided equally by Maryland and Federal funds.

The average annual rainfall in Maryland exceeds 7,000 billion gallons. Nature consumes 60 percent in evapo-transpiration, leaving 2,800 billion gallons to replenish surface waters and ground waters. One-half of this is surface runoff that provides the floodflow of streams. The other half is ground-water recharge which overfills the ground-water reservoirs and spills out of them continuously. It provides the sustained flow of streams between periods of rainfall when there is no surface runoff.

The highest per capita water consumption in Maryland is in Baltimore City. Extrapolated to include the entire State, Maryland would need only 190 billion gallons of water a year.

Compilation of actual consumption data gives a consumption of 40 billion gallons of ground water and 110 billion gallons of surface water a year, a total of 150 billion gallons a year. Present consumption is only 5.7 percent of the rate of replenishment. The other 94.3 percent is being discharged to waste into the ocean.

Obviously there is no water resources problem in Maryland. Water problems in Maryland can be only water supply problems. Water supply problems arise because nature has not made these overabundant water resources available everywhere in the quantity needed and at the rate need at the time needed.

AVAILABILITY OF MARYLAND'S WATER RESOURCES

In the Tidewater counties, comprising 54 percent of the land area of Maryland, nature has solved these water supply problems with its ground-water resources, mainly in its artesian aquifers but also in its water-table aquifers. All of Tidewater Maryland is underlain by one or more ground-water reservoirs. The storage capacity of these water-bearing sands and gravels is enormous. Their transmissibilities are high. Wells with sustained yields of hundreds of gallons a minute can be developed, unaffected by the most severe and most prolonged droughts imaginable.

Surface water resources play a lesser role and are less widely available in the Tidewater counties. The soil is so porous that surface runoff is less than average. Countless tidal estuaries penetrate far inland. Stream courses above the brackish tidal waters are short and are not numerous.

In central and western Maryland, comprising 46 percent of the land area of the State, the rocks are generally impermeable and water occurs generally only as water-table water in small and narrow crevices and openings in the rocks. The transmissibility of these aquifers is low. The average yield of wells is less than 15 gallons a minute. The storage is small and becomes depleted when rainfall is deficient. In dry periods the yields of wells decrease and wells even go dry. Storage, however, is replenished immediately by substantial rainfall, and the yield of wells is restored. Large sustained yields of ground water are not generally obtainable in central and western Maryland.

On the other hand, surface runoff and groundwater overflow into streams are greater than average. Stream courses are longer and streams are more numerous. Streamflow is more than 16 inches per acre in the drainage basins. Large and sustained yields of water are obtainable throughout central and western Maryland from surface waters. But only the water in transit in the stream at the time water is needed is automatically available. During periods of low flow, the quantity in transit is inadequate to sustain large yields. Nature has not provided large storage reservoirs to hold its replenishment of surface waters as she has to hold the replenishment of ground waters in the Tidewater counties. Large sustained yields of surface waters are obtainable, but only by storing the flood waters in reservoirs behind dams.

STATUS OF USERS OF WATER RESOURCES IN MARYLAND

The uses of water resources are: (1) domestic (for the household, family farm animals, poultry, and other livestock, and the family garden and lawn); (2) public water supplies; (3) industrial; (4) supplemental crop irrigation.

1. Domestic use

Sustained domestic supplies are available everywhere, and generally more conveniently as ground water. It is both reasonable and practicable to continue their exemption from control. The domestic user has no water resources or water supply problems in Maryland that he cannot solve for himself.

2. Public water supplies

No municipality in Maryland has been unable to find ample water resources. Distribution systems have fallen behind increasing demands resulting from increasing population and increasing per capita consumption, so that use restrictions have had to be placed on consumers at the delivery points of distribution systems that have not kept pace with increasing peak demands. In the Tidewater counties the artesian aquifers, and even the water-table aquifers, have adequate storage for sustained yields, unaffected by periods of deficient rainfall. In central and western Maryland, where dependent on surface waters, public water supplies are financially able to provide storage to tide over dry periods of inadequate streamflow.

Public water supplies in Maryland have no water resources problem. To what extent their distribution system is geared to meet expanding peak demands, is merely a supply problem that the taxpayers decide for themselves.

3. Industrial use

Water resources are so ample that industries in Maryland have had no problem in locating where an adequate supply can be developed, obtaining adequate sustained yields of ground water in the Tidewater counties without the need to provide artificial storage, or obtaining sustained yields of surface water in central and western Maryland by providing storage reservoirs behind dams, insofar as low and drought flows may be inadequate.

Maryland's industrial users have no water resources or water supply problems they have not been able to solve for themselves, or the solutions of which have been impeded by the control to which they have been subjected under the Maryland law since January 1, 1934.

4. Supplemental irrigation

Adequate ground-water resources are available throughout Tidewater Maryland for supplemental irrigation. Adequate supplies are obtainable from properly completed wells. The appropriation and use of water for irrigation is now exempt from control. The only irrigation water supply problem is the economic question whether the water is

worth the cost of the well required to supply the water.

Amendment of the law to include under its control the use of water for irrigation would not decrease the water resources available for irrigation nor adversely affect obtaining the supply. Control is needed only to protect the irrigator and the people of Maryland against infiltration of brackish tidal water into the aquifers through improperly placed wells and to protect the irrigators' wells against decline in yield through overlapping cones of depression resulting from improperly placed wells.

In central and western Maryland large sustained yields of water for irrigation are obtainable from and only obtainable from surface waters. But surface waters are deficient in quantity at the time the yields are needed for irrigation. Large sustained yields for irrigation require storage reservoirs.

Though the use of surface waters for irrigation is exempt from control under the Maryland policy of the 1933 act, the rights to surface waters are restricted to riparian owners. Yet the volume of water in the streams, both as surface runoff and as sustained ground-water overflow, comes equally acre for acre from the total acreage of the drainage basins of each stream. Now the nonriparian owners in a drainage basin contribute proportionally to the streamflow but only the riparian owners have rights to use the water, even though 94.3 percent of the water is discharged to waste into tidal waters.

The irrigators in central and western Maryland have two problems: (1) Legal—the nonriparian owners having no rights to the surface waters and the riparian owners having uncertain and undefined limited rights; (2) the economic problem of financing storage. The latter is a heavier financial burden than the wells of the Tidewater irrigators. The solution of the economic problem is merely whether the value of the water for irrigation is worth the cost of storing it. The legal problem is solvable only through appropriate legislation.

THE RIPARIAN RIGHTS FETISH

The solution of the legal problem of the irrigators dependent on surface waters has been blocked in Maryland, as well as in other humid States, by adherents to the fetish of riparian rights.

The riparian rights of the individual riparian owners are limited by the riparian rights of all the rest of the riparian owners. The only unchallengeable rights of a riparian owner are unrestricted use for domestic purposes of water left in a stream after all riparian owners upstream have satisfied their unrestricted domestic needs. The downstream riparian owners are "entitled to have the water flow through their lands undiminished in quantity," except for that which the riparian owners above them are entitled to take for their domestic needs. The riparian owners' rights do not include uses of water for industrial or irrigation purposes. These uses are designated "artificial" uses. Because the riparian rights per se permit the use of so little of available streamflow, reasonable withdrawals for artificial needs from the much more that runs to waste are condoned by the courts. But the riparian owner who exceeds his riparian rights by taking water for artificial needs has his permissible uses limited to what is reasonable in relation to the reasonable artificial needs of the other riparian owners. That limitation is subject to all the circumstances surrounding each particular case. It would be more orderly and more satisfactory for the irrigators to have the limitations of their reasonable uses determined in advance under the control provided by the Maryland law than to have the uses challenged and perhaps denied in court afterward.

C. E. Busby, the recognized authority on water law in the U.S. Department of Agriculture, aptly characterizes the riparian doctrine as a "system ever contracting, never expanding." The fallacy in the riparian rights fetish is that the riparian rights of the individual riparian owner are looked at only under high magnification and the restrictions imposed upon his riparian rights by the riparian rights of the rest of the riparian owners are viewed only under a powerful reducing lens, or even wholly ignored.

INDUSTRIAL USERS UNDER THE MARYLAND POLICY

The industrial users of the waters of the State have been subject to the policy of the control of the appropriation or use of the waters of the State in the interest and welfare of the people of Maryland since January 1, 1934, a period of 24 years. Permits have been applied for to take quantities of water ranging from a few hundred gallons of water a day for roadside drive-ins to millions of gallons a day by major industries. No applicant has been denied the quantity of water applied for. No applicant has failed to obtain the quantity applied for. No applicant has appealed against conditions in the permit issued to him even to the local circuit court. No riparian owner has charged violation of his riparian rights in the granting of any permit. The Maryland policy has successfully and satisfactorily proven its merit for 24 years in its application to the needs for all users of water subject to its control. If ever "the proof of the pudding is the eating," the Maryland policy has been proven.

IRRIGATION USERS EXCLUDED FROM THE MARYLAND POLICY

Supplemental irrigation had not been practiced and its practice was wholly unforeseen in 1933. The enactment of the Maryland policy was unwittingly so phrased as not to include supplemental irrigation under that policy. The supplemental irrigators are the only users of water for artificial purposes that claim to be in need of a solution of a water problem in Maryland. The Maryland law has inadvertently and unintentionally left them out in the cold.

The water needs of the irrigators lie well within the extremes of the roadside drive-in (greatly exceeding those) and the needs of the large industries (much less than those). Certainly the burden of proof that the Maryland policy is not applicable to water when it is to be used to irrigate is upon the "farm leaders" who oppose its application to water used for irrigation. Certainly there is nothing inherent in the policy itself that makes it operable when the water is used in a food-processing plant (industrial use) but makes it inoperable if the water is used instead on the food-growing fields in the vicinity. Certainly it is immaterial to the water resources themselves whether the water they yield is applied to processing food or to growing food. Certainly illogical is the position of those who repeatedly cry pressing need for an immediate solution of their legal problem yet oppose a long-tested and proven solution on the ground there is no immediate need for a solution of their legal problem. Their opposition is the more unreasonable in that their repeated efforts to find an alternative legal solution have met with repeated failure. They object to control of the water resources of the State in the interest and welfare of the whole people of the State when used for irrigation under the delusion the policy would impair their riparian rights, even though prohibited in the law. Yet having both unimpaired riparian rights and exemption from control, they labor under the handicap of an unsolved legal problem, that the Maryland policy solved 24 years ago for the industrial users.

THE WATER RESOURCES OF MARYLAND

That there is a water problem is generally recognized. That the problem will become more acute as water consumption increases is true. There has been much discussion of the problem by those who have disregarded facts and drawn erroneous conclusions. Inadequacy of water supply facilities have been wrongly ascribed to inadequacy of water resources. On the basis of this false premise, falling ground-water levels and decreasing streamflows have been postulated, though such evidences of depleting water resources do not exist.

Water is unique in being the only mineral resource that is replenishable. An insufficiency of water resources can arise only if the rate of consumption exceeds the rate of replenishment. Such a situation does not exist and cannot arise in the foreseeable future.

Magnitude of the water resources

The average annual rainfall in Maryland exceeds 40 inches. The land area of Maryland is 9,887 square miles. The average annual rate of replenishment of water in Maryland is, therefore, more than 7 trillion gallons. Nature consumes 60 percent of this in evapo-transpiration, leaving 40 percent for the replenishment of ground water and surface water, amounting to 2.8 trillion gallons. One-half of this, 1.4 trillion gallons, is surface runoff which provides floodflow of streams. The other half, 1.4 trillion gallons, is ground-water recharge which overfills the ground-water reservoirs and spills out of them to provide the sustained flow of streams between periods of rainfall. Thus each year Maryland receives an increment of new water, initially equally divided between ground water and surface water, amounting to 1.4 trillion gallons each, equivalent to at least 8 inches of ground water and at least 8 inches of surface water. Insofar as the ground-water recharge is not consumed. it finds its way into the streams to augment the streamflow up to a total of more than 16 inches.

The most intensely concentrated use of water, both per capita and per unit area, is in Baltimore City. The consumption of water in Baltimore City in 1954 was 62 billion gallons, just about the same as the average annual rainfall on Baltimore City and at the rate of 200 gallons per person. The population of Maryland is 2,602,000. Even at the Baltimore City rate of consumption, Maryland would need only 520 billion gallons of water annually, whereas the rate of replenishment is 2,800 billion gallons, or more than five times as much.

The estimated consumption of ground water in the 19 Maryland counties in which the state-wide inventory has been completed is 100 million gallons a day. The total for the 23 counties does not exceed 110 million gallons a day, or 40 billion gallons a year. The rate of ground-water replenishment is 1,400 billion gallons a year, or 35 times as much as the consumption.

The average amount of water needed for supplemental irrigation is estimated at about 8 inches. Even if the entire surface of Maryland were brought under supplemental irrigation, less than the replenishment of ground water or less than the replenishment of surface water, or less than one-half of the total annual replenishment would be adequate. This is the ultimate maximum that irrigation would consume.

Obviously even the most extravagant estimates of future water supply requirements fall far short of the rate of replenishment.

What is the water problem

The water problem is solely an economic problem. Maryland's water resources are more than adequate to supply whatever quantity of water may be demanded wherever and whenever needed. The water problem is whether the delivered water is worth the cost of delivery to the consumer. The water problem is to control the appropriation and the use of water in such manner and to such extent as to make the delivery price as economical as is compatible with the best interests of the people of Maryland.

The control over the use and appropriation

Under the 1933 Water Resources Act, Maryland asserted control over the use and appropriation of the waters of the State "in order to conserve, protect, and utilize the water resources of the State in accordance with the best interests of the people of Maryland." That act prohibits the use and appropriation of any waters without a permit from the department of geology, mines, and water resources. The act provides if the commission of the department "be of the opinion that the proposed appropriation of State waters will be detrimental to the best public interest, the commission may reject the application or it may include in the grant of the permit such conditions, terms, and reservations with respect to the character, amount, means, and manner of such use as it may deem reasonably necessary to preserve the proper control in the State and to insure the safety and welfare of the people of Maryland." However, the act exempts from this control approved municipal water supplies, domestic uses, and farm uses.

The control had been adequate and effective for surface waters. It was ineffective for ground water until it was supplemented by the Well Control Act in 1945, requiring the licensing of well drillers and requiring permits to drill wells. With the advent of supplemental irrigation, the control has become inadequate because of the exemption of farm uses. Its adequacy can be restored by repealing the exemption for irrigation uses.

The water resources inventory

The ground-water inventory.—A systematic inventory of the ground-water resources of the Baltimore industrial area was started late in 1942. In 1945 the scope of the inventory was expanded to ultimately cover the entire State. The investigations are conducted cooperatively by the U.S. Geological Survey and the Maryland Department of Geology, Mines, and Water Resources. The results are published by the department of geology, mines, and water resources.

The investigations have been completed and the results have been published covering the Baltimore industrial area, the five southern Maryland counties (Anne Arundel, Calvert, Prince Georges, Charles, and St. Marys), the three lower Eastern Shore counties (Somerset, Wicomico, and Worcester), two of the central Maryland counties (Howard and Montgomery), and Garrett County in western Maryland. The investigations have been completed and the reports are being prepared for printing covering the other six counties on the

Eastern Shore (Caroline, Dorchester, and Talbot; and Cecil, Kent, and Queen Annes) and Baltimore and Harford Counties. The investigations in Carroll and Frederick Counties are in progress. The investigations in Allegany and Washington Counties will be started in 1956.

Availability of ground-water resources.—Ground water occurs in unconfined aquifers under water table conditions in which the static water level is the level at which the unconfined water stands. Its replenishment is from rain that falls in its vicinity. The water level fluctuates through an annual cycle, decreasing throughout the growing season and increasing throughout the period between growing seasons.

Artesian water occurs in confined aquifers under hydrostatic pressure. Recharge takes place in the outcrop area of the aquifer, and the hydrostatic pressure increases with increasing depth of the aquifer which may extend miles from the recharge area. The water in an artesian well rises higher than the aquifer to a level of equilibrium with the hydrostatic pressure in the aquifer.

When a well is pumped the water level falls in the well an amount proportional to the rate of pumping. The decrease in pressure causes surrounding water in the aquifer to flow toward the well, resulting in lowering the water level in the vicinity. Since the circumference of the area of reduced pressure increases rapidly away from the well, the amount of lowering of the water level decreases rapidly with increasing distance from the well. The shape of the hydrostatic surface around a well is that of an inverted cone with its apex at the well, which is called the cone of depression. When pumping ceases water levels gradually rise to the level of static equilibrium. The rate at which water may be withdrawn from an aquifer without exceeding the rate of recharge is called the safe yield of the aquifer. That rate depends on the hydrologic properties of the aquifer. It varies in aquifers and in different parts of the same aquifer. So long as the "safe yield" is not exceeded, the water is continuously available in undiminished quantity.

The geology of Maryland is such that wells with yields of hundreds of gallons a minute can be developed in the tidewater counties from both water table aquifers and artesian aquifers. The recharge rate and the transmissibility of these aquifers is high. There is no need to exercise restrictive control over the quantity desired for supplemental irrigation. The only control needed is to control well locations, so that the cone of depression at one irrigation well does not appreciably affect the yields of nearby irrigation wells and that irrigation wells are so located that the cone of depression will not cause recharge in the aquifer from saline tidewaters. The control provided in the Water Resources Act would afford this protection if the use and appropriation of water for irrigation were placed under that control. Fresh water streams are relatively small and their courses are short so that surface waters are not generally available in tidewater Maryland. Ground water must be the main source of water for supplemental irrigation in the tidewater counties. The ground-water resources are adequate and there are no serious economic supply problems.

In central and western Maryland ground water occurs mostly under water table conditions. The rocks themselves are dense and impermeable. Water occurs in constricted openings in the rocks. Storage is relatively small and transmissibility is low. Yield of wells rarely exceeds tens of gallons a minute and the average yield is about 15 gallons a minute. To obtain yields satisfactory for irrigation would require a number of wells. Though the annual potential recharge is more than 8 inches and its volume is more than 200,000 gallons per acre, the water in storage is not adequate to the temporary high rate of withdrawal required by irrigation. Ground water is not generally a satisfactory or economically practicable source of water for supplementary irrigation in central and western Maryland, so that little need for control over its use will arise. Surface water must be the main source of water for supplemental irrigation in central and western Maryland.

Geographically distributed through Maryland are 105 observation wells in which fluctuations in water levels are measured. These records are published annually in water supply papers by the U.S. Geological Survey. The records are summarized in the county water resources Bulletins published by the department of geology, mines, and water resources. Except in a few restricted areas of heavy pumpage for industrial and public water supply consumption these records show no sustained decrease in water levels.

The surface water inventory.—Surface waters are inventoried by continuous measurements of the volume of streamflow at stream-gaging stations. The flow measurements are tabulated as minimum, maximum, and average flow per day in each month, as inches and volume per square mile of drainage area of a stream by months and as average discharge in gallons per day per square mile of drainage area in each month. These monthly records are consolidated into averages for the year, and the yearly averages into averages for the period of record of the station. The records thus give the minimum recorded drought flow, the maximum recorded floodflow and the average flow of the streams.

The stream-gaging stations are operated cooperatively by the U.S. Geological Survey and the Maryland Department of Geology, Mines, and Water Resources. The annual records are published annually in Water Supply Papers by the U.S. Geological Survey. The department of geology, mines, and water resources published in 1944 a summary of the records from 1892 to 1943. A summary of records after 1943 up to the date of publication is included in the county water resources bulletins published by the department of geology, mines, and water resources.

At present 85 gaging stations are in operation on Maryland streams covering Maryland geographically, by stream sizes, and by stream types. By comparing spot measurements on ungaged streams and on gaged streams, the flow characteristics of ungaged streams can be predicted with reasonable accuracy.

Availability of surface water resources.—Surface water is available naturally only in the volume that is in transit as streamflow at the time of consumption. There is no large natural storage of surface water to cushion peak demands analogous to the large volume of water stored in the ground water aquifers.

The nature of the demand for surface water supplies has been such that the control under the Water Resources Act has been adequate. The large demands have been for industry and for public water supplies and have been confined mainly to central and western Maryland.

With an average streamflow of about 8 billion gallons a day, there has been no problem of adequacy of surface water resources. Industry has had no difficulty in locating itself on a stream with adequate flow. Insofar as minimum drought flow may have been inadequate, industry has provided storage reservoirs behind dams. Public water supplies have had less latitude in choice of location of their sources of water, but they have also overcome inadequacies during periods of low flow by storing behind dams during periods of surplus flow. The daily average consumption of surface water in Baltimore City is 170 million gallons. An estimate of twice that amount for the State would doubtless be too large. Yet 340 million gallons a day is less than 4 percent of the surface water resources. The surface water problem of industrial and municipal supplies is an economic problem which has not been beyond their capacity to solve—the cost of the water supply system.

The use of surface water for irrigation presents an entirely new and more complex problem. The need for irrigation water comes when there is no surface runoff and when streamflows are lowest. The surface water in transit as streamflow is available only to those with riparian rights. The quantity in transit is inadequate, and its use and appropriation is restricted to the point of prohibition by the law of riparian rights. The solution of the problem is obvious; the practicability of the solution is an economic question.

The average annual surface runoff is more than 8 inches or more than 200,000 gallons per acre, one-half of which is adequate for irrigation. The farm pond program points to one solution of the surface water irrigation problem. The problem is an individual one for each prospective irrigation installation: Will the impounded water be worth the cost of impoundment? In some cases it will be, in other cases it will not.

The average annual streamflow is more than 16 inches over the entire watershed of a stream. The amount is far more than needed to satisfy riparian rights on the stream. A riparian owner can store enough water in a reservoir behind a dam to supply his irrigation needs during periods of high water in the stream and thus not interfere with riparian rights by not intercepting the flow during periods of low water. The problem is an economic problem of the cost of storing the water and not one of inadequacy of water resources. On an individual basis this solution may in some cases be impossible because of the unsuitability of the terrain for reservoir storage.

The terrane difficulty can be solved by voluntary collective action within a watershed or within portions of a watershed under the existing exemption of farm use from the control of the Water Resources Act and without violation of riparian rights, that is under existing laws, if the beneficiaries are willing to pay their proportionate shares of the cost.

Precedent for another solution of the economic problem is the procedure established by law for the installation of shore erosion protection works with public funds. This law authorizes a county, upon petition of 75 percent of the beneficiaries, to borrow funds for the installation and to amortize the bonds by an annual tax assessment levied against the beneficiaries. Similarly by compulsory collective action, the irrigation needs of riparian land owners can be provided by constructing dams to create adequate storage reservoirs.

SUMMARY

Maryland receives annually 7 trillion gallons of water. Nature consumes 4.2 trillion gallons through evapotranspirtation. Ground water recharge takes 1.4 trillion gallons. That which is not withdrawn by wells, spills out of the overfilled ground-water reservoirs to provide the sustained flow of streams between periods of rainfall. Surface runoff takes 1.4 trillion gallons which provides the flood flow of streams.

Maryland consumes about 40 billion gallons of ground water annually and not more than 120 billion gallons of surface water annually. The annual consumption of ground water is less than 3 percent of the annual replenishment. The annual consumption of surface water is less than 9 percent of the flood flow of the streams and less than 4.5 percent of the total flow of the streams. The combined consumption of ground water and surface water is less than 6 percent of the annual replenishment.

The water problem in Maryland is not a problem of inadequacy or impending inadequacy of water resources. Maryland will always have adequate water resources—at a price. The problem is to supply the water in the quantity needed when needed and where needed by the consumers. The problem is the economic problem of cost of water supply systems and control over the use and appropriation of the more readily available supplies to the best interests of all of the consumers.

Heretofore it has been satisfactory to leave to each consumer the solution of his own economic problem of water supply. Existing laws, the 1933 Water Resources Act and the 1945 Well Control Act, have provided adequate control over the use and appropriation.

The practice of supplemental irrigation has made existing control inadequate because of the exemption of farm uses from that control. Adequate control can be restored by bringing the use of water for irrigation under the control of the Water Resources Act.

The hydrologic conditions in Maryland are such that the problem of irrigation water supplies is more easily solved in tidewater Maryland through the utilization of ground water. The resources are far more than adequate. The only control needed is to assure proper well locations. In central and western Maryland the economic problem of ground-water supply precludes the use of ground water for irrigation purposes. Hydrologic conditions provide the principal control and will adequately supplement the legal control over the use and appropriation of ground water in central and western Maryland. The solution of the economic problem of ground-water supplies can still be left to each consumer.

The lack of natural storage of surface water to cushion peak demands, in contrast to the adquate natural storage of ground water, and the distribution problems arising from the law of riparian rights do not permit as easy a solution of the surface water-supply problem for irrigation uses.

Because the irrigation water-supply problem of tidewater Maryland is satisfactorily solved through the use of ground water, tidewater Maryland is not confronted with the complexity of the surface-water problem. Central and western Maryland are beset with the surface-water irrigation supply problem. Surface-water resources are more than adequate, but the natural supply is inadequate when needed for irrigation. The only solution of the supply problem is storage. The storage problem is an economic problem. For individual irrigation consumers the solution of the economic problem will often be prohibitive and even impossible under the law of riparian rights. Collectively the problem is more often solvable both economically and within the law of riparian rights. Voluntary collective action is usually unattainable and unsuccessful. Successful collective action requires the replacement of the law of riparian rights with legislated collective action whereby the required storage is provided and its cost is distributed among the consumers proportional to their withdrawals from the supply. Such collective action is applicable to portions of watersheds and to whole watersheds.

(Report of committee to study water resources: Joseph T. Singewald, Jr., chairman; Ralph Dulaney; Herbert R. Hoopes; Senator Joseph A. Mattingly; Paul McAuliffe; William Schluderberg; Harry H. Rieck, ex officio.)

October 28, 1955.

MASSACHUSETTS

THE COMMONWEALTH OF MASSACHUSETTS,
EXECUTIVE DEPARTMENT,
Boston, September 25, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D. C.

DEAR SENATOR KERR: Reference is made to your letter of June 23, 1959, relative to the provisions of Senate Resolution 48, establishing the Senate Select Committee on National Water Resources. In your letter you requested information in regard to the water problems of this State, both at present and those anticipated to arise between now and 1980.

The water resources of Massachusetts have been one of the most important factors in the industrial development of this Commonwealth. We have been fortunate in having an abundance of water of naturally good quality for domestic water supply purposes, industrial water, the development of water power and hydroelectric projects, recreation and agricultural purposes.

Since World War II, there has been an increased demand for water for the above purposes. Undoubtedly one of the biggest factors has been the great increase in the demand of water for recreational purposes. This has led to increased public demand for accelerating the program of stream pollution control.

The responsibility for the solution of water resource problems has been shared in Massachusetts by six State agencies. The need for coordinating the activities of these agencies, plus the need of coordinating the State's activities with the Federal Government activities in this field, led to the passage of legislation which created the Water Resources Commission (ch. 620 of the acts of 1956, a copy of which is attached). That commission is now engaged in obtaining basic data and coordinating the activities of the State agencies in this field.

Massachusetts has been subjected to a number of disastrous hurricanes and floods in the last three decades. It was found that flood protection could be obtained in a number of the river valleys by the construction of flood control reservoirs in the upstream States. This led to the mechanism of the use of interstate compacts between the various New England States. At the present time, Massachusetts is a member of three such interstate flood control compact groups. A similar situation existed in the field of pollution control and Massachusetts then joined with the other New England States and New York State in an interstate pollution control compact. The mechanism of the interstate compact has been very successful in carrying out the objectives of those compacts.

The most comprehensive study ever undertaken in the New England area in regard to natural resources was the study made between 1950 and 1955 by the New England-New York Inter-Agency Committee (NENYIAC) which was financed by the Federal Government. The report gave an inventory and blueprints for the future development of the New England resources.

In 1956 the New England Governors' conference established, in cooperation with the Federal Government, a northeastern resources committee to implement the work and recommendations of the NENYIAC report. It was subsequently found that the work of this committee could be more effectively carried out by the use of the interstate compact mechanism. As a result, there was enacted recently in Massachusetts legislation to permit it to join with the other Northeastern States in the so-called northeastern resources compact for the development of water and related land resources. It is anticipated that the necessary legislation will be filed in the forthcoming session of Congress to secure congressional approval of this compact.

As the problem of water resource development has been so closely allied with the economic development of the Commonwealth, the legislature has authorized numerous studies to be made of public water resource problems. Six of these reports [1] are submitted for the information of your committee. In addition, it has authorized an appropriation of funds to be matched by Federal funds for obtaining basic data, such as stream gaging measurements, quality of water studies, the determination of the availability of ground water and rainfall gages. Projects for stream clearance, flood control, and pollution control have been financed by the Commonwealth or jointly with the Federal and municipal governments.

A sanitary engineering experimental station was established in 1886, the Lawrence Experiment Station, the first one in this country for research in the methods for treatment of water. The experiment station was completely rebuilt in 1952 using only State funds.

It is my understanding that your committee is planning to hold a hearing in Boston on December 8, 1959. I am requesting the water resources commission and the other State agencies who are members of that commission to prepare additional information for presentation at that hearing.

It was noted that the membership of your committee does not contain any representatives from the New England States. I feel that this is rather unfortunate in view of the fact that New England water laws, policy, and problems are so different from those in the western portion of our country. This should be taken into consideration in any attempt to formulate a national water policy.

I appreciate the opportunity of being able to present the views of Massachusetts and will look forward to welcoming the members of your committee to Massachusetts on December 8.

Sincerely yours,

Foster Furcolo.

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[1] Not reprinted herein.

MICHIGAN

State of Michigan,
Water Resources Commission,
Lansing, Mich., August 13, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources, U.S. Senate, Washington, D.C.

Dear Senator Kerr: You have Governor Williams' letter of July 3 in response to yours of June 23 and the task assigned us growing out of S. Res. 48.

Following my appearance before you and members of the Senate Public Works Committee on July 14 with respect to H.R. 1, I had lunch with members of Senator Hart's staff and a short chat with our junior Senator.

Out of all this came notice that Senator Hart would be chairing that section of your committee's hearings held in our Great Lakes region in the fall. This has been subsequently scheduled for October 29 in Detroit.

In moving promptly to meet Senator Hart's request for appropriate suggestions we felt we would be meeting your needs as well.

The attached transmittals of July 16,[1] 23, and 27 [1] will place you in possession of everything that has so far gone forward in response to your request via Senator Hart.

May I add this comment: What should be done toward solution of the listed problems is, as indicated, to a considerable degree, a question of finance. We show early needs in municipal water supply, municipal sewage disposal, and flood control alone totaling nearly a billion dollars. On the basis of past policy and practice, local units of government must be looked to for assuming virtually the entire responsibility for this financing. Similarly, much needed developments in agricultural water-supply storage will, under accepted philosophy in Michigan, have to "pay their own way" as have the State's huge drainage improvements, inland lake level stabilization programs, beach erosion control projects, and other water resource management measures.

In one area particularly, that of Great Lakes levels control, very active participation by the Federal Government would appear eminently appropriate and in fact indispensable. We had one brief warning back in 1951–52 of the ruin that could be visited on our shores by protracted high levels such as have occurred many times in the past. The injuries resulting from abnormally low levels can be almost equally disastrous. The rapidly intensifying usage of these great waters is enormously magnifying the potential for damage by extremes of level fluctuation either way.

Should either you or Senator Hart need further information or comment from us, we are always on call.

Very truly yours,

Milton P. Adams, *Executive Secretary.*

State of Michigan,
Water Resources Commission,
Lansing, Mich., July 23, 1959.

Senator Philip Hart,
Senate Building, Washington, D.C.

Dear Senator Hart: The attached has been prepared for me by Chief of our Hydrology Division. It outlines the problems with which we are familiar dealing with water. Some of the matters are correctly State responsibility, others are Federal, others are local, and some are combinations.

In view of my chat last Tuesday with Bill and Muriel I felt this outline would be a beginning from which you could decide in which direction we might go farther, having in mind the hearings you will be conducting this fall in the Great Lakes area.

Very truly yours,

Milton P. Adams, *Executive Secretary.*

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[1] Not printed.

MEMORANDUM

To: Mr. Adams.
From: N. Billings.
Date: July 22, 1959.

The following outline of water resource uses and problems is submitted for your use in connection with Senator Hart's request.

I. USES

A. Supply

1. *Municipal.*—Based on information supplied from local officials, an estimated $398 million capital investment for improvements and expansion of municipal water-supply facilities should be expanded by 1965 to meet the minimum needs. Involves problems of financing, intermunicipal coordination, surveys (mainly of ground water) and water rights.

2. *Industrial (nonmunicipal).*—Problem greatest in southeast Michigan metropolitan area where underground source formations are scarce and interior streamflow erratic.

3. *Irrigation.*—Presently concentrated in limited portion of the State but is growing and spreading rapidly. Involves problems of water rights, reservoir evaporation, and seepage control. Poses growing threat to established essential water uses by depleting streamflow and lake levels during periods of water shortage.

B. Waste assimilation

1. *Municipal.*—Based on information supplied from local officials an estimated $540 million for improvement and expansion of municipal collection and treatment facilities should be expanded by 1965. Involves problems of financing, intermunicipal coordination, surveys (mainly surface waters), and conflicting consumptive water uses.

2. *Industrial.*—Continued industrial expansion on interior waters calls for intensified research on improved waste-treatment methods—may necessitate low streamflow augmentation by reservoir construction and operation. Failure of these two approaches to provide means for solution of the problem may bring an early end to industrial expansion at some locations.

C. Power development

1. *Hydro.*—Drought time supply being depleted by diversion for irrigation. Problem will grow.

2. *Thermal.*—Reducing waste-assimilating capacity of streams at some interior location. Also subject to injury by diversion for irrigation.

D. Navigation

Increased commercial and recreational usage appears to be aggravating problems of safety.

Commercial vessels are causing serious erosion problems along some connecting rivers.

Waste disposal is requiring greater attention as numbers of vessels and pleasure craft increases.

Need indicated for prevention of such accidents as November oil-barge sinking in southern Lake Michigan.

E. Recreation

Calls for medium and stable Great Lakes levels, stabilized flow and levels of interior waters, freedom from pollution and siltation in all waters.

Need for public access, parks, and other recreation areas is becoming critical.

II. DAMAGES

A. Flood control

Completion of Corps of Engineer reports lag because of lack of sufficient personnel to process authorized and funded studies. Authorized projects on the saginaw River, Grand River at Lansing, and the Kalamazoo River at Kalamazoo call for new Federal contributions of some $34 million. Local cash contributions of $8,787,000 for these same projects raise problems of financing and intergovernmental unit coordination.

Local zoning of flood plains needs emphasis.

B. Drainage

Particularly acute in the southeast Michigan metropolitan area. A number of large drainage projects involving several millions of dollars raise problems of financing and intergovernmental unit coordination.

C. Beach erosion

Caused an estimated $22 million damage along Michigan's Great Lakes shores during brief high-water period of early fifties. If past levels are a valid criteria, future problem could become catastrophic. Involves primarily problem of lake-level control, financing of protective works, zoning of shore-area development.

III. SURVEYS AND INVESTIGATIONS

State is not keeping up with needs in stream gaging, ground-water surveys, meteorological-data collection, and other hydrological fact finding and research.

ABSTRACT OF REPORT TO THE SELECT SENATE COMMITTEE ON NATIONAL WATER RESOURCES, DETROIT, MICH., OCTOBER 29, 1959

(By Milton P. Adams, executive secretary, Michigan Water Resources Commission)

[The full report is printed as a part of pt. 7 of the committee hearings, Detroit, Mich.]

Resources

Miles of streams: 36,350.
Inland lakes: 11,037.
Square miles of Great Lakes waters: 39,000.
Miles of Great Lakes shoreline: 3,251.
Inches average annual precipitation: 31.7.

Uses [1]

Recreation.
Power.
Municipal and industrial supply.
Agriculture.
Sewage and waste effluent assimilation.

Problems [1]

Expansion of municipal water and sewer facilities.
Flood control.
Streamflow stabilization.
Beach-erosion control.
Great Lakes level control.
Pollution control.
Water rights.
Collection of basic data.

PROBLEM EXPANSION

Municipal sewer and water needs

Our 1955 survey for the Governor's Conference on "Michigan's Water, Sewer, and Drainage Needs" showed that the State's municipalities must spend close to $1 billion by 1965 to provide needed water and sewer facilities. This does not include cost of Lake Huron water intakes for Flint and Detroit area. Information available to us indicates that contracts are being let at only about half the rate necessary to meet the above objective.

Flood control

Michigan has been fortunate in its freedom from floods during recent years. However, serious floods have occurred in the past and we know that they will again.

Only one Federal flood-control project is now under construction in Michigan. Several others have been authorized and are now awaiting Federal appropriations. Favorable action is currently recommended.

It is believed that the national interest as well as that of the States and local communities warrants a nationwide survey of flood problems and the development of cooperative governmental programs to control further development in flood areas as well as to correct existing problems where economically and socially justified.

Streamflow stabilization

Since most uses of streams must be geared to assured minimum flow, a very large portion of total streamflow escapes without serving much if any purpose. Increasing the minimum flow calls for construction and operation of reservoir networks. Sites for such reservoirs are at a premium in Michigan as well as in many other States.

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[1] Within the purview of this agency's report.

These sites are rapidly being developed for other purposes which will remove them from availability for water storage.

A comprehensive survey of reservoir sites is required, with development as the need appears. This is believed to be a field in which Federal as well as State and local interests should participate.

Land-management programs to control waterway siltation must be effected in order to prevent loss of reservoir space.

Beach-erosion control

The Great Lakes beaches are peculiarly vulnerable to beach erosion because of long-term variations in water level. Damages accrue to private as well as public properties. The value of Great Lakes beaches to the Nation warrants more active participation in beach-erosion control. Basic Federal law should be made consistent with flood-control law as to participation policy.

Great Lakes levels control

Extremes of variation in lake levels are highly injurious to shore properties and water-using interests. Control of these variations, now under study by the Corps of Engineers, should be effected expeditiously, as may be indicated by the study results.

Control of further development of shore properties is a governmental responsibility. If local units of government do not assume responsibility the public interest may require action by higher levels of government.

Water-pollution control

Navigational: Increased navigation resulting from the seaway and from expanding public interest in pleasure boating is bringing on a problem of pollution resulting from navigation.

This is creating a need for clarification of authority among the Canadian and American Federal agencies and the States and Province of Ontario and the development of effective policing mechanisms to control waste disposal from vessels, also to prevent marine accidents resulting in polluting cargo loss.

Land based: Control of pollution is a State responsibility, with Federal intervention called for only when States fail to solve problems in interstate or international waters. The Federal grant program of aid to municipalities under Public Law 660 of 1956 should be at least doubled. A research program of improved methods for sewage treatment is badly needed. This should be headed up by the U.S. Public Health Service, with an appropriation of $1 million to $3 million a year for the next 10 years.

LIST OF EXHIBITS IN REPORT TO U.S. SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES

GENERAL EXHIBITS

1. The Michigan law (Act 245, P.A. 1929 as amended by Act 117, P.A. 1949).
2. Pollution Control Duties and Policies of the Michigan Water Resources Commission (June 1, 1955).
3. Organization Diagram.
4. Final Report of a Canvass of Michigan's Local Government Needs for New Water and Sewage Works Capital Improvements Over the Next Ten Years (October 1955—reprinted, March 1958).
5. Where Do We Get Our Water and How Much Do We Have? (Norman Billings, June 8, 1959.)
6. Water Resources as Viewed by a State Agency (Milton P. Adams—presented at the Federation of Sewage and Industrial Wastes Association, Dallas, Tex., October 12, 1959).[1]

POLLUTION CONTROL EXHIBITS

7. Michigan Water Resources Commission—Final Orders of Determination—Industrial (Status, April 1, 1959).[1]
8. Michigan Water Resources Commission—Orders of Determination—Industrial—New or Increased Use (Status, April 1, 1959).[1]
9. Michigan Water Resources Commission—Final Orders of Determination—Municipal—Outstanding as of April 1, 1959.[1]
10. Michigan Water Resources Commission—Final Orders of Determination—Municipal—Required Projects Completed (April 1, 1959).[1]
11. Michigan Water Resources Commission—Industrial Pollution Status (April 1, 1959).

HYDROLOGY EXHIBITS

12. Water Resources Conditions and Uses in the Huron River Basin (1957).[1]
13. Flow Characteristics of Representative Michigan Rivers (August 1957).[1]
14. Progress Toward Water Rights Legislation in Michigan (Norman Billings, October 15, 1957).
15. Water Use for Irrigation (1959).

EXHIBIT NO. 1

State of Michigan, Water Resources Commission

ACT 245, PUBLIC ACTS OF 1929, AS AMENDED BY ACT 117, PUBLIC ACTS OF 1949[2]

AN ACT to create a water resources commission to protect and conserve the water resources of the state, to have control over the pollution of any waters of the state and the great lakes, with power to make rules and regulations governing the same, and to prescribe the powers and duties of such commission; to prohibit the pollution of any waters of the state and the great lakes; to designate the commission as the state agency to cooperate and negotiate with other governments and agencies in matters concerning the water resources of the state; and to provide penalties for the violation of this act

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[1] Not printed herein.

[2] Effective May 18, 1949.

SECTION 1. For the purpose of carrying out the provisions of this act there is hereby created a water resources commission, hereinafter referred to as the commission, which shall consist of the director of conservation, the commissioner of health, the highway commissioner, the director of agriculture and 3 citizens of the state to be appointed by the governor, by and with the advice and consent of the Senate, 1 from groups representative of industrial management, 1 from groups representative of municipalities, and 1 from groups representative of conservation associations or interests, for terms of 3 years each; provided, that of the members first appointed, 1 shall be appointed for a term of 1 year, 1 for a term of 2 years, and 1 for a term of 3 years. Vacancies shall be filled for the unexpired term in the same manner as original appointments. Members of the commission shall be entitled to actual and necessary expenses incurred in the performance of official duties. It shall be the duty of the department of administration to provide suitable office facilities for the use of the commission.

Each of the aforesaid state officers is hereby authorized to designate a deputy of his department to serve in his stead as a member of the commission.

SEC. 2. The commission shall organize and make its own rules and regulations and procedure and shall meet at least once each month and shall keep a record of its proceedings. The commission shall protect and conserve the water resources of the state and shall have control of the pollution of surface or underground waters of the state of Michigan and the great lakes, which are or may be affected by waste disposal of municipalities, industries, public or private corporations, individuals, partnership associations, or any other entity. The commission is empowered to make or cause to be made surveys, studies and investigations of the uses of waters of the state, both surface and underground, and to cooperate with other governments, governmental units and agencies thereof in making such surveys, studies and investigations. The commission shall assist in an advisory capacity any flood control district which may be authorized by the legislature of this state. The commission in the public interest shall have the right and duty to appear and present evidence, reports and other testimony during the hearings involving the creation and organization of flood control districts. It shall also be the duty and responsibility of the commission to advise and consult with the legislature on the obligation of the state to participate in the costs of construction and maintenance as provided for in the official plans of any flood control district or intercounty drainage district. The commission shall have the authority to, and shall enforce the provisions of this act and shall make and promulgate such rules and regulations as shall be deemed necessary to carry out the provisions of this act. The rules and regulations of the commission shall be promulgated in conformity with the provisions of Act No. 88 of the Public Acts of 1943, as amended, being sections 24.71 to 24.82 inclusive, of the Compiled Laws of 1948.

SEC. 2A. The water resources commission is hereby designated the state agency to cooperate and negotiate with other governments, governmental units and agencies thereof in matters concerning the water resources of the state, including but not limited to flood control and beach erosion control. The commission is further authorized to take such steps as may be necessary to take advantage of any act of Congress heretofore or hereafter enacted which may be of assistance in carrying out the purposes of this act.

The commission shall report to the governor and to the legislature at least once in each year any plans or projects being carried on or considered and shall include in such report requests for any legislation needed to carry out any proposed projects or agreements made necessary thereby, together with any requests for appropriations.

SEC. 3. The commission shall be authorized to bring any appropriate action in the name of the people of the State of Michigan, either at law or in chancery as may be necessary to carry out the provisions of this act, and to enforce any and all laws relating to the pollution of the waters of this state.

SEC. 4. The commission or any agent duly appointed by it shall have the right to enter at all reasonable times in or upon any private or public property for the purpose of inspecting and investigating conditions relating to the pollution of any waters of this state. The commission shall have the right to call upon any officer, board, department, school, university or other state institution and the officers or employees thereof for any assistance deemed necessary to the carrying out of this act.

SEC. 5. The commission shall establish such pollution standards for lakes, rivers, streams and other waters of the state in relation to the public use of which they are or may be put, as it shall deem necessary. It shall have the authority to ascertain and determine for record and in making its order what volume of water actually flows in all streams, and the high and low water marks of lakes and other waters of the state, affected by the waste disposal or pollution of municipalities, industries, public and private corporations, individuals, partnership associations, or any other entity. It shall have the authority to make regulations and orders restricting the polluting content of any waste material or polluting substance discharged or sought to be discharged into any lake, river, stream, or other waters of the state. It shall have the authority to take all appropriate steps to prevent any pollution which is deemed by the commission to be unreasonable and against public interest in view of the existing conditions in any lake, river, stream, or other waters of the state.

SEC. 6. It shall be unlawful for any person to discharge or permit to be discharged into any of the lakes, rivers, streams, or other waters of this state any substance which is injurious to the public health or to the conducting of any industrial enterprise or other lawful occupation; or whereby any fish or migratory bird life or any wild animal or aquatic life may be destroyed or the growth or propagation thereof be prevented or injuriously affected or the value of lawfully taken fish or game be destroyed or inpaired as the consequence of said pollution. Any person who shall discharge or permit to be discharged any waste or pollution into any of the waters of this state, in contravention of the above provisions of this section, shall be deemed to violate the provisions of this act.

Sec. 7. Whenever in the opinion of the commission any person shall violate or is about to violate the provisions of this act, or fails to control the polluting content or waste discharged or to be discharged into any waters of the state, the commission may notify the alleged offender of such determination by the commission. Said notice shall contain in addition to a statement of the specific violation which the commission believes to exist, a proposed form of order or other action which it deems appropriate to assure correction of said problem within a reasonable period of time and shall set a date for a hearing on the facts and proposed action involved, said hearing to be scheduled not less than 4 weeks or more than 8 weeks from the date of said notice of determination. Extensions of the date of hearing may be granted by the commission or on request. At such hearing any interested party may appear, present witnesses and submit evidence. Following such hearing, the final order of determination of the commission upon such matter shall be conclusive: *Provided*, That such order may be reviewed de novo in the circuit court for the county of Ingham, in chancery, or for the county in which such alleged violator resides, or for the county in which said alleged violation occurred, upon petition therefor, filed within 15 days after said final order of determination.

Sec. 8. (A) Whenever any person shall feel himself aggrieved by the restriction of polluting content or waste, or pollution, or any other order of the commission, he shall have a right to file a sworn petition with the commission, setting forth the grounds and reasons for his complaint and asking for a hearing of the matter involved. The commission shall thereupon fix the time and place for such hearing and shall notify the petitioner thereof. At such hearing the petitioner and any other interested party may appear, present witnesses and submit evidence. Following such hearing, the final order of determination of the commission upon such matter shall be conclusive: *Provided*, That such order may be reviewed de novo in the circuit court for the county of Ingham, in chancery, or for the county in which such alleged violator resides, or for the county in which such alleged violation occurred.

(B) Coincident with the effective date of this amendatory act, it shall be the duty of any person then or thereafter requiring a new or substantial increase over and above the present use now made of the waters of the state for sewage or waste disposal purposes, to file with the commission a written statement setting forth the nature of the enterprise or development contemplated, the amount of water required to be used, its source, the proposed point of discharge of said wastes into the waters of the state, the estimated amount so to be discharged, and a fair statement setting forth the expected bacterial, physical, chemical and other known characteristics of said wastes. Within 60 days of receipt of said statement, it shall be the duty of the commission to make an order stating such minimum restrictions as in the judgment of the commission may be necessary to guard adequately against such unlawful uses of the public waters as are set forth in section 6 above. If the order is not acceptable to the applicant, he may request a hearing on the matter involved, following which the commission's final order of determination in this connection shall be conclusive: *Provided*, That such order may be reviewed de novo in the circuit court for the county of Ingham, in chancery, or for the county in which such alleged violator resides, or for the county in which said alleged violation occurred, upon petition therefor, filed within 15 days after such final order of determination is adopted: *Provided further*, That failure to comply with the final order of the commission under this section of the act shall not be considered a violation of this act unless and until such failure results in pollution contrary to section 6 of this act.

Sec. 9. Any duly appointed agent of the commission shall have authority to enforce the provisions of this act and may make criminal complaint against any person violating the same. After service of a written notice of determination setting forth specifically any violation of this act, any person who shall fail to comply with the order of the commission shall be subject to the penalties of this act.

Any person who willfully violates any provision of this act or any restriction, regulation or final order of determination of the commission made thereunder, shall be subject to a penalty of not to exceed $500.00 per day for each and every day of such violation, such penalty to be recovered in a suit in the circuit court.

Sec. 11. Wherever the word "person" is used in this act, it shall be construed to include any municipality, industry, public or private corporation, co-partnership, firm or any other entity whatsoever. Wherever the words "waters of the state" shall be used in this act, they shall be construed to include lakes, rivers and streams and all other water courses and waters within the confines of the state and also the Great Lakes bordering thereon.

Sec. 12. This act shall not be construed as repealing any of the provisions of the law governing the pollution of lakes and streams, but shall be held and construed as ancillary to and supplementing the same and in addition to the laws now in force, except as the same may be in direct conflict herewith.

Sec. 12A. The provisions of this act shall be construed as supplemental to and in addition to the provisions of Act No. 316 of the Public Acts of 1923, as amended, being sections 261.1 to 277.10, inclusive, of the Compiled Laws of 1948; and nothing in this act shall be construed to amend or repeal any law of the state of Michigan relating to the public service commission, the department of conservation and the department of health relating to waters and water structures, or any act or parts of acts not inconsistent with the provisions of this act.

Exhibit No. 2

Pollution Control Duties and Policies of the Michigan Water Resources Commission

Unlawful pollution of the waters of the State is clearly defined by statute. Section 6 of Act 245, Public Acts of

1929, as amended by Act 117, Public Acts of 1949, reads as follows:

"Sec. 6. It shall be unlawful for any person to discharge or permit to be discharged into any of the lakes, rivers, streams, or other waters of this state any substance which is injurious to the public health or to the conducting of any industrial enterprise or other lawful occupation or whereby any fish or migratory bird life or any wild animal or aquatic life may be destroyed or the growth or propagation thereof be prevented or injuriously affected or the value of lawfully taken fish or game be destroyed or impaired as the consequence of said pollution. Any person who shall discharge or permit to be discharged any waste or pollution into any of the waters of this state, in contravention of the above provisions of this section, shall be deemed to violate the provisions of this act."

It is the duty of the commission to secure the abatement of existing pollution and to prevent the occurrence of unlawful pollution which could result from new or increased uses of the waters of the State for waste disposal.

The above-mentioned statute calls for certain procedures to be followed by the commission in securing pollution abatement. First, for abatement of existing pollution, the alleged offender must be served a notice by the commission of its determination that he is violating the law, and in what specific respects. The notice shall contain a statement of the restrictions upon his pollution which the commission is considering imposing. It shall also set the date for a hearing when everyone concerned may appear and present information and evidence. After the hearing the commission may determine that action by it is not warranted or it may issue an order to the offender, establishing requirements either as originally proposed or as modified in the light of information brought out at the hearing. The order states what is to be accomplished (not specifically what shall be done to accomplish it) and by what date.

In addition to the above steps, the commission takes the following action as a matter of policy: When the commission's staff first determines, through its surveys, that unlawful pollution appears to exist, a member contacts the offending city or industry apprizing them of the survey findings. He explains what should be done to correct the situation, and a good percentage of pollution problems are solved at this stage through cooperative compliance—simply by staff working with the polluter and helping him plan and apply appropriate corrective measures.

Where the polluter fails to take the necessary action under staff urging, the problem is brought to the attention of the commission which may, if it thinks the problem serious, ask him to come in for a conference. The conference permits full exploration of the situation and presentation of commission policy and duties. Such conferences frequently tend to resolve differences to the benefit of both the polluter and the commission.

Hearings must conform to requirements of the administrative procedure which insures all parties full opportunity to present their case.

Reference to the courts by either party of a duly adopted order is authorized

Although alleged financial inability to comply with commission orders doesn't constitute a legal defense of noncompliance, the commission in its determination can take into account financial and other problems of the polluter in setting the abatement date. Extensions of time may be and often are granted where it can be shown that delay in complying with commission orders is unavoidable and does not result from neglect. In the past, the commission was willing in some cases to accept pledges that pollution would be abated, in lieu of issuing an order. However, abuses of that arrangement in which, it developed, the offender participated only as a subterfuge to qualify for Michigan Department of Health sewer-construction permits, led to its abandonment, and orders are now issued in all cases where the State alleges unlawful pollution.

Persons proposing new or extended uses of the waters of the State for waste disposal must file a statement with the commission describing such use. The commission may then order such restrictions as it deems necessary to prevent unlawful pollution. Hearings and court reference are provided.

Classification of streams is contrary to Michigan practice. The fullest possible use of streams for all beneficial purposes is encouraged as long as the doctrine of reasonable use is observed. The law makes certain declared injuries the measure of unlawfulness in waste disposal and does not envision the relegation of any Michigan streams to the condition of open sewers.

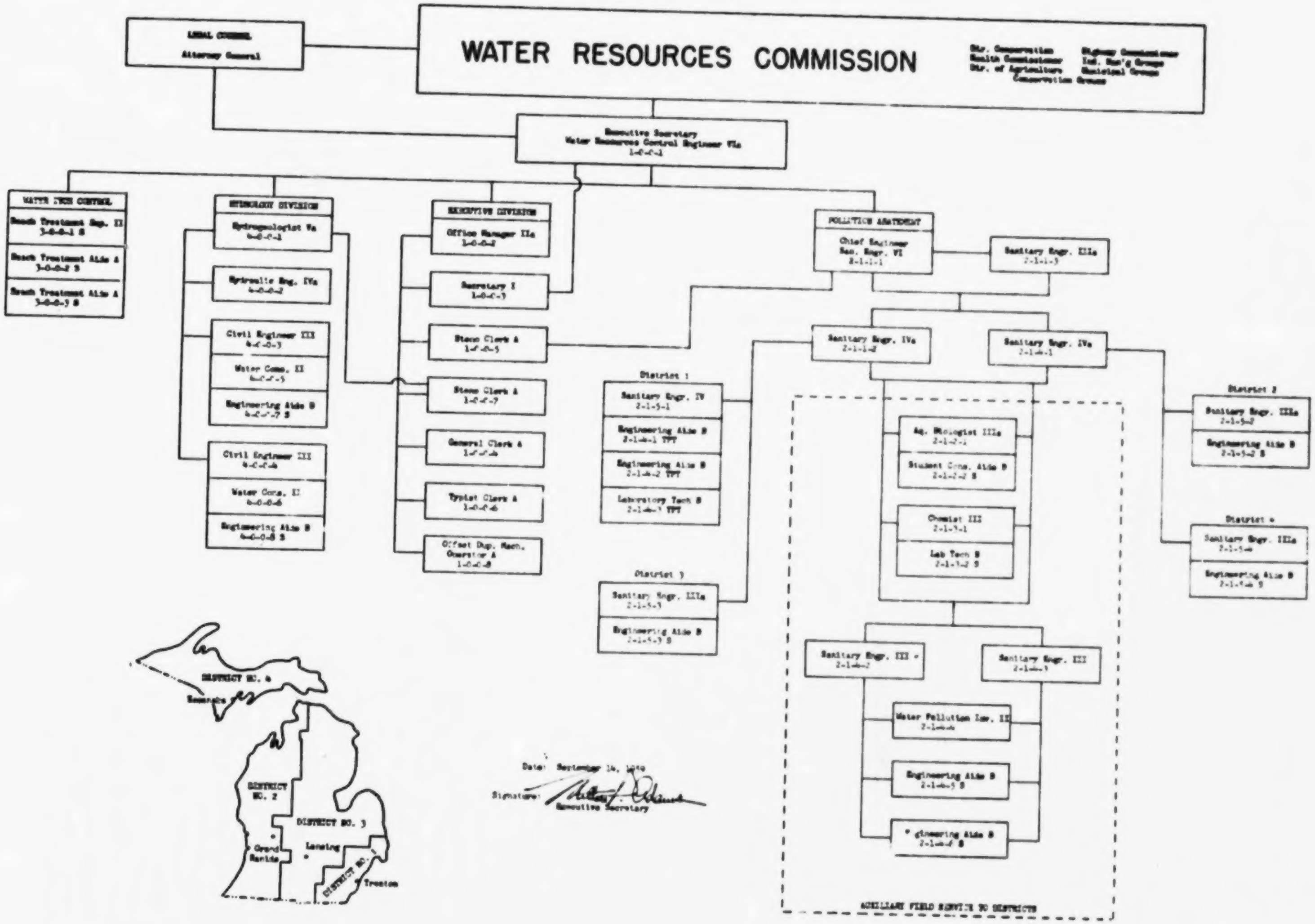
Commission orders are restrictive, not permissive. In no case does the commission state or imply that it is issuing permission to put wastes into the waters of the State. The law does not authorize any issuance of permits. The order only states what restrictions the commission is imposing, to stop or prevent such pollution as, by statutory definition, would be unlawful. Any riparian, with respect to surface waters, or any affected property owner, with respect to ground water, is free to take independent action against the polluter, and the commission itself is free to issue further restrictions, after proper notice and hearing as above when the pollution has become unlawful due to changed upstream or downstream uses.

It is said that this flexibility may penalize industry by making it impossible to determine in advance how far the commission may ultimately go in imposing waste-disposal restrictions. The answer to that is that water has become too valuable a resource to define, in one order for all time, the extent of its conservation. As time goes on, it is certain that increasing public and private water-use requirements will call for continued reduction of its use as a vehicle for waste disposal.

It follows, therefore, that, when users multiply along streams where the assimilating value of the resource remains the same and becomes fully utilized, waste loadings must be reduced to maintain a lawful stream quality.

(Prepared by staff, June 1, 1955.)

Exhibit No. 3


WATER RESOURCES COMMISSION
Dir. Conservation
Health Commissioner
Dir. of Agriculture
Highway Commissioner
Ind. Rep's Group
Municipal Group
Conservation Groups
LEGAL COUNSEL
Attorney General
Executive Secretary
Water Resources Control Engineer VIa
1-0-0-1
WATER TECH CONTROL
Beach Treatment Sup. II
3-0-0-1 B
Beach Treatment Aide A
3-0-0-2 B
Beach Treatment Aide A
3-0-0-3 B
HYDROLOGY DIVISION
Hydrogeologist Va
4-0-0-1
Hydraulic Eng. IVa
4-0-0-2
Civil Engineer III
4-0-0-3
Water Cons. II
4-0-0-5
Engineering Aide B
4-0-0-7 B
Civil Engineer III
4-0-0-4
Water Cons. II
4-0-0-6
Engineering Aide B
4-0-0-8 B
EXECUTIVE DIVISION
Office Manager IIa
1-0-0-2
Secretary I
1-0-0-3
Steno Clerk A
1-0-0-5
Steno Clerk A
1-0-0-7
General Clerk A
1-0-0-4
Typist Clerk A
1-0-0-6
Offset Dup. Mach. Operator A
1-0-0-8
POLLUTION ABATEMENT
Chief Engineer
San. Engr. VI
2-1-1-1
Sanitary Engr. IIIa
2-1-1-3
Sanitary Engr. IVa
2-1-1-2
Sanitary Engr. IVa
2-1-4-1
District 1
Sanitary Engr. IV
2-1-5-1
Engineering Aide B
2-1-4-1 TPT
Engineering Aide B
2-1-4-2 TPT
Laboratory Tech B
2-1-4-3 TPT
District 3
Sanitary Engr. IIIa
2-1-5-3
Engineering Aide B
2-1-5-3 B
Aq. Biologist IIIa
2-1-2-1
Student Cons. Aide B
2-1-2-2 B
Chemist III
2-1-3-1
Lab Tech B
2-1-3-2 B
Sanitary Engr. III
2-1-4-2
Sanitary Engr. III
2-1-4-3
Water Pollution Inv. II
2-1-4-4
Engineering Aide B
2-1-4-5 B
gineering Aide B
2-1-4-6 B
AUXILIARY FIELD SERVICE TO DISTRICTS
District 2
Sanitary Engr. IIIa
2-1-5-2
Engineering Aide B
2-1-5-2 B
District 4
Sanitary Engr. IIIa
2-1-5-4
Engineering Aide B
2-1-5-4 B
DISTRICT NO. 4
Escanaba
DISTRICT NO. 2
Grand Rapids
DISTRICT NO. 3
Lansing
DISTRICT NO. 1
Trenton

Date: September 14, [illegible]

Signature:
Executive Secretary

EXHIBIT No. 4

STATE OF MICHIGAN,
November 7, 1955.

To: Hon. G. Mennen Williams, Governor; members of legislature, members of water resources commission, participating governmental units, others interested.

From: Milton P. Adams, executive secretary, water resources commission.

Subject: Final report on 1955 canvass of local governmental needs for new water and sewage works capital improvements over the next 10 years.

A major problem facing many municipalities in Michigan today is the matter of financing needed water and sewage works facilities. The facilities are necessary to overcome present deficiencies; also to cope with the demands imposed by the State's increasing population and industrial expansion. Following the public announcement by the U.S. Department of Commerce[3] that the total needs for the Nation for water and sewage works expansion within the next 10 years would amount to $25.3 billion, it was decided to ascertain what Michigan's share in this total might be. The same Federal agency simultaneously announced a $92 billion need for highways of the Nation and $41.5 billion for schools and educational buildings.

A questionnaire was prepared and submitted to 352 governmental subdivisions of the State, seeking their best estimates of what it might cost to provide the needed water and sewage works facilities during the next 10 years. The original request went out July 18, with some followup letters during August. From the 260 reports received, as of September 30, a weighted estimate was prepared to include the total urban population of Michigan. No attempt has been made to canvass the separate and independent needs of industry.

Governor Williams was advised of the survey proposal at a conference in his office in July. He requested that he be advised of the results of the canvass upon its completion. The work was performed under a statutory directive in which "the commission is empowered to make or cause to be made surveys, studies, and investigations of the uses of the waters of the State, both surface and underground, and to cooperate with other governments, governmental units, and agencies thereof in making such surveys, studies, and investigations.

Following a progress report submitted to Governor Williams on September 26, 1955, a detailed study of the answers received has been completed. Data have been checked to avoid duplication. They are arranged by population size groupings in the following pages.

All data submitted from the southeastern Michigan urban area, defined as including the counties of Wayne, Oakland, Macomb, Monroe, Washtenaw, and St. Clair, have been arranged as section I of this report. This six-county area contains approximately two-thirds of the State's urban population. Since World War II it has continued to expand rapidly in population growth as well as industrial development. This metropolitan "spill" has resulted in water-supply and sewage-disposal problems that may exceed $1 billion before adequate facilities are provided, according to other estimators.

The balance of the State has been included in section II.

In each section of the report the municipalities reporting having been listed with their own estimates of cost of needed water and sewage works facilities. The per capita investment need of the reporting municipalities was determined by dividing their total estimated costs for new water and sewage works facilities by their 1950 population. The per capita investment becomes a weighted base which we have assumed as the average per capita investment for the entire urban population living in the area. Using the total urban population of each area, an estimate of the total water and sewage works needs was then determined. Section III is a summation of sections I and II, the entire State need for new capital improvements over the next 10 years. The itemized total stands at $937.4 million, of which $539.6 million is needed for new lateral and intercepting sewers, sewage pumping, and sewage treatment, while $397.9 million is needed for new water production, storage, transmission, and distribution facilities. It does not appear from the answers received that the latter sum includes any part of a suggested $300 million Lake Huron-Detroit area pipeline proposal that has been mentioned in occasional news reports during the summer and fall.

To the best of our knowledge, these totals exceed the prospective requirement of any similar period in the State's history. The financial means of meeting such a requirement, traditionally a wholly local governmental responsibility, is by no means generally assured. Yet the early undertaking of such a program is essential, as we see it, to the protection of the public interest in this rapidly expanding period of development of the State.

MARCH 1958.

SPECIAL NOTE.—Subsequent to enactment of Public Law 660 in 1956, 24 municipalities whose needs had been set forth in this summary have qualified for Federal construction grants. Five other municipalities whose needs were not listed in the summary have qualified for Federal grants toward local sewage-plant construction.

Municipalities marked * have qualified for Federal construction grants.

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[3] Engineering News-Record, June 2, 1955.

SECTION I

Southeastern Michigan urban area

Class (1)	Total water works expansion (2)	Total estimated sewage works expansion (3)	Total estimated cost of expansion (4)	1950 population (5)
Cities (over 10,000 population) [1]	$140, 324, 890	$213, 494, 702	$353, 819, [illegible]	2, 563, 264
Authorities	79, 925, 000	106, 700, 000	186, 625, 000	
Cities (2,500-10,000 population) [1]	5, 458, 465	7, 652, 000	13, 110, 465	99, 062
Cities (under 2,500 population) [1]	2, 385, 465	5, 060, 250	7, 495, 715	24, 878
Townships	36, 850, 000	56, 757, 500	93, 607, 500	303, 523
Total	264, 943, 820	380, 664, 452	654, 658, 272	2, 990, 752
Total southeastern Michigan urban population				[2] 3, 109, 514

Estimated per capita expenditures for waterworks expansion	$88. 58
Estimated per capita expenditures for sewage works expansion	130. 29
Total estimated expenditures for waterworks expansion in southeastern urban Michigan	275, 440, 750. 00
Total estimated expenditures for sewage works expansion in southeastern urban Michigan	405, 138, 579. 00
Total estimated expenditures for needed water and sewage works expansion in southeastern urban Michigan	680, 579, 329. 00

[1] Includes both cities and villages.

[2] Included total urban population of the 6-county area as reported in 1950 Federal census plus 133,171 persons residing in townships known to have water-supply and sewage problems, in the fringe areas of metropolitan centers. These persons were not included in the census "urbanized" count.

Units reporting from southeastern Michigan urban area (counties of Wayne, Oakland, Macomb, Monroe, Washtenaw, and St. Clair)

Municipality	Waterworks expansion						Sewage works expansion						
	Production facilities	Storage	Transmission mains	Distribution mains	Other miscellaneous	Total water	Lateral sewers	Internal sewers	Pumping	Treatment	Other miscellaneous	Total sewage	Grand total
CITIES OF OVER 10,000 POPULATION													
Allen Park [1]													
Ann Arbor						$500,000	$728,466		$39,236			$767,702	$1,267,702
Birmingham	$500,000	$200,000	$200,000	$50,000		950,000	400,000	$100,000		$350,000		850,000	1,800,000
Dearborn [4]			600,000	200,000		800,000	300,000	300,000	50,000	500,000		1,150,000	1,950,000
Detroit	15,000,000	4,000,000	10,000,000	5,000,000	$5,000,000	39,000,000	2,500,000	150,000,000	2,500,000	6,000,000		161,000,000	200,000,000
East Detroit [2]													
Ecorse		150,000		500,000		650,000	100,000					100,000	750,000
Ferndale	403,450		244,700	100,000		748,150	3,500,000	150,000				3,650,000	4,398,150
Grosse Pointe Park				8,000		8,000	25,000		10,000			35,000	43,000
Hamtramck								2,500,000				2,500,000	2,500,000
Hazel Park		400,000	100,000	25,000		525,000	25,000	1,800,000	175,000			2,000,000	2,525,000
Highland Park	410,000	300,000			100,000	810,000							810,000
Lincoln Park		250,000	10,000	50,000	50,000	360,000		550,000	200,000			750,000	1,110,000
Livonia				6,000,000		6,000,000	11,250,000					11,250,000	17,250,000
Monroe	200,000	150,000	200,000	200,000		750,000	200,000	200,000	50,000	300,000		750,000	1,500,000
Mount Clemens	810,000	100,000	75,000			985,000		150,000				150,000	1,135,000
Pontiac	61,000,000	3,000,000	10,000,000	900,000	6,490,000	81,390,000	15,000,000	2,700,000	500,000	5,300,000		23,500,000	104,890,000
Port Huron	2,265,500	167,000	514,240	187,000		3,133,740	500,000	2,507,000	60,000			3,067,000	6,200,740
River Rouge		150,000		600,000		750,000	200,000					200,000	950,000
Roseville [2]													
St. Clair Shores [2]													
Wyandotte	750,000		500,000			1,250,000		500,000				500,000	1,750,000
Ypsilanti	765,000	300,000	450,000	100,000	100,000	1,715,000	300,000	400,000	75,000	500,000		1,275,000	2,990,000
Southeastern Oakland County Water Authority	225,000	800,000	1,000,000			2,025,000							2,025,000
South Macomb Sanitary District	9,900,000	2,000,000	2,000,000	2,000,000	1,500,000	17,400,000	20,000,000	20,000,000	2,000,000	5,000,000		47,000,000	64,400,000
Wayne County Board of Road Commissioners	40,200,000	4,500,000	15,800,000			60,500,000		46,700,000		13,000,000		59,700,000	120,200,000
CITIES OF OVER 2,500 BUT LESS THAN 10,000 POPULATION													
Center Line [2]													
Clawson	$50,000	$100,000	$300,000	$100,000		$550,000	$300,000	$1,600,000	$100,000			$2,000,000	$2,550,000
Garden City [1]													
Grosse Pointe Farms	165,000		150,000			295,000		320,000				320,000	615,000
Harper Woods		300,000		200,000		500,000		100,000	50,000			150,000	650,000
Holly	11,000			20,000		31,000		140,000		$240,000		380,000	411,000
Huntington Woods							50,000	125,000				175,000	175,000
Marine City	225,000	150,000	50,000	50,000	$100,000	575,000	500,000	150,000	80,000	200,000		930,000	1,505,000
Marysville	200,000	50,000		200,000		450,000	200,000					200,000	650,000
Melvindale				135,000	105,000	240,000		180,000			$12,000	192,000	432,000
Milan	12,000	50,000		100,000	5,000	167,000	250,000	250,000	20,000	30,000		550,000	717,000
Oak Park	119,000	264,000	375,000	113,000		871,000	87,000	75,000				162,000	1,033,000
Pleasant Ridge		216,000			25,000	241,000		900,000				900,000	1,141,000
Plymouth	240,000	100,000	375,000	100,000		815,000	400,000	200,000				600,000	1,415,000
Romeo	23,500		10,000	25,000		58,500				45,000		45,000	103,500
St. Clair [4]	77,000	100,000		168,373	50,000	385,373	100,000	258,000	30,000	230,000		618,000	1,003,373
Wayne				250,000		250,000	200,000	200,000	30,000			430,000	680,000

See footnotes at end of table, p. 126.

Units reporting from southeastern Michigan urban area (counties of Wayne, Oakland, Macomb, Monroe, Washtenaw, and St. Clair)—Continued

CITIES OF LESS THAN 2,500

Municipality	Waterworks expansion						Sewage works expansion						
	Production facilities	Storage	Transmission mains	Distribution mains	Other miscellaneous	Total water	Lateral sewers	Internal sewers	Pumping	Treatment	Other miscellaneous	Total sewage	Grand total
Bloomfield Hills	$44,000	$30,000	$60,000	$30,000	$16,000	$180,000	$100,000	$120,000	---	---	---	$220,000	$400,000
Clarkston	15,000	75,000	20,000	100,000	---	210,000	150,000	---	$20,000	$50,000	---	220,000	430,000
Farmington	72,000	154,000	62,000	35,000	---	373,000	100,000	80,000	46,000	---	$320,000	546,000	919,000
Fraser	95,000	40,000	30,000	50,000	---	215,000	80,000	80,000	50,000	210,000	---	420,000	635,000
Lake Orion	16,000	---	10,000	4,000	---	30,000	8,000	10,000	10,000	75,000	---	103,000	133,000
Lathrup Village	---	---	50,985	194,409	---	245,394	670,700	157,550	---	---	---	828,250	1,073,644
Manchester	65,000	---	40,000	40,000	---	145,000	50,000	73,000	---	145,000	40,000	308,000	543,000
New Baltimore	82,000	60,000	15,000	15,000	---	172,000	220,000	20,000	---	200,000	---	440,000	612,000
Memphis	8,000	---	10,000	10,000	---	28,000	---	---	---	---	---	175,000	203,000
Orchard Lake	90,000	11,000	250,000	150,000	---	501,000	750,000	400,000	100,000	100,000	---	1,350,000	1,851,000
Oxford	---	---	---	---	---	13,071	---	---	---	---	---	---	13,071
Petersburg	---	---	---	---	---	75,000	---	---	---	---	---	80,000	155,000
Richmond	35,000	50,000	15,000	8,000	---	108,000	35,000	50,000	---	75,000	---	160,000	268,000
Roosevelt Park	---	---	---	75,000	---	75,000	160,000	---	---	---	---	160,000	235,000
Sylvan Lake	10,000	---	---	---	5,000	15,000	---	---	15,000	35,000	---	50,000	65,000
TOWNSHIPS													
WAYNE COUNTY													
Canton Township	---	---	---	---	---	$12,500,000	---	---	---	---	---	$12,500,000	$25,000,000
Brownstown Township	---	$200,000	$800,000	$500,000	$300,000	1,800,000	$2,000,000	$1,500,000	$500,000	$1,500,000	---	5,500,000	7,300,000
Dearborn Township	---	---	---	1,000,000	---	1,000,000	3,000,000	---	---	---	---	3,000,000	4,000,000
Ecorse Township	---	---	300,000	150,000	150,000	600,000	300,000	2,500,000	---	---	---	2,800,000	3,400,000
Northville Township [1]	---	---	---	---	---	---	---	---	---	---	---	---	---
Redford Township	---	---	200,000	150,000	---	350,000	500,000	5,000,000	---	---	---	5,500,000	5,850,000
Taylor Township	---	---	2,000,000	4,000,000	---	6,000,000	8,000,000	3,500,000	---	---	---	11,500,000	17,500,000
OAKLAND COUNTY													
Avon Township	60,000	60,000	12,000	400,000		532,000	400,000	150,000	30,000	500,000		1,080,000	1,612,000
Farmington Township	---	---	---	---	---	1,608,000	---	---	---	---	---	2,000,000	2,608,000
Southfield Township	---	---	1,000,000	5,295,000	---	6,295,000	502,500	2,300,000	400,000	---	---	3,202,500	9,497,500
Royal Oak Township	100,000	---	1,000,000	2,000,000	---	3,100,000	2,000,000	---	100,000	---	---	2,100,000	5,200,000
Troy Township	180,000	300,000	450,000	300,000	200,000	1,430,000	---	---	---	---	---	---	1,430,000
Waterford Township	---	---	100,000	235,000	---	335,000	3,000,000	800,000	300,000	---	---	4,100,000	4,435,000
West Bloomfield Township	40,000	---	---	160,000	---	200,000	1,000,000	600,000	---	---	---	1,600,000	1,800,000
MACOMB COUNTY													
Warren Township [2]	---	---	---	---	---	---	---	---	---	---	---	---	---
Erin Township [3]	---	---	---	---	---	---	---	---	---	---	---	---	---
WASHTENAW COUNTY													
Pittsfield Township	---	---	---	---	---	300,000	400,000	300,000	---	---	---	700,000	1,000,000
Ypsilanti Township	300,000	---	100,000	500,000	---	900,000	600,000	200,000	---	375,000	---	1,175,000	2,075,000

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[1] Supplied by Wayne County system.

[2] See South Macomb Sanitary District.

[3] Reports no expected expenditures.

SECTION II

Urban units in Michigan (less southeastern Michigan urban area)

Class (1)	Total waterworks expansion (2)	Total estimated sewage works expansion (3)	Total estimated cost of expansion (4)	1950 population (5)
Cities (over 10,000 population) [1]	$45, 962, 660	$37, 575, 696	$83, 538, 356	838, 051
Cities (2,500-10,000 population) [1]	13, 455, 904	14, 558, 748	28, 014, 652	234, 618
Cities (under 2,500 population) [1]	7, 796, 042	16, 437, 272	24, 233, 314	98, 047
Townships and authorities	28, 485, 913	36, 509, 773	64, 995, 686	107, 903
Total	95, 700, 519	105, 081, 489	200, 782, 008	1, 278, 619
Total Urban Population (less Southeastern Michigan)				[2] 1, 635, 644

Estimated per capita expenditures for waterworks expansion	$74. 85
Estimated per capita expenditures for sewage works expansion	82. 18
Total estimated expenditures for waterworks expansion in Michigan (less southeastern Michigan)	122, 427, 953. 00
Total estimated expenditures for sewage works expansion in Michigan (less southeastern Michigan)	134, 417, 224. 00
Total estimated expenditures for needed water and sewage works expansion in Michigan (less southeastern Michigan)	256, 845, 177. 00
Total for southeastern Michigan (see sec. I)	680, 579, 329. 00

SECTION III

Total estimated expenditures for needed water and sewage works expansion in Michigan (all urban units) $937, 424, 506

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[1] Includes both cities and villages.

[2] Includes total urban population of Michigan less 6-county area (southeastern Michigan urban area) as reported in 1950 Federal census plus 107,903 persons residing in townships known to have water-supply and sewage problems, located in fringe areas of metropolitan centers. These persons were not included in census "urbanized" count.

Urban units reporting (excluding southeastern Michigan)

CITIES OF OVER 10.000 POPULATION

Municipality	Waterworks expansion						Sewage works expansion						
	Production facilities	Storage	Transmission mains	Distribution mains	Other miscellaneous	Total water	Lateral sewers	Internal sewers	Pumping	Treatment	Other miscellaneous	Total sewage	Grand total
Adrian	$915,000	$188,000	$109,600	$386,000		$1,598,900	$500,000	$100,000		$1,000,000		$1,600,000	$3,198,900
Alpena	50,000			1,500,000		1,550,000	930,000		$30,000			960,000	2,510,000
Battle Creek	76,000		500,000	400,000		976,000	500,000			3,250,000		3,750,000	4,726,000
Benton Harbor	50,000	300,000		100,000	$2,000,000	2,450,000				350,000		350,000	2,800,000
Cadillac	862,000	137,000	275,000	351,000		1,625,000						575,000	2,200,000
East Lansing	81,000	45,000	50,000	250,000		426,000	25,000	1,500,000		2,150,000		3,675,000	4,101,000
Escanaba	50,000			200,000		250,000	85,000	80,000	10,000	25,000		200,000	450,000
Grand Rapids*						2,500,000							2,500,000
Holland							1,322,800			1,003,900		2,326,700	2,326,700
Ironwood*	53,000	30,000	20,000			103,000	30,000	20,000	15,000	250,000		315,000	418,000
Jackson	1,290,000	100,000	200,000	70,000	50,000	1,710,000	150,000	2,500,000	25,000	200,000		2,875,000	4,585,000
Kalamazoo	375,000	200,000	250,000	750,000	175,000	1,750,000	900,000	250,000	150,000			1,300,000	3,050,000
Lansing	1,327,000		1,250,000	1,250,000	110,000	3,937,000	750,000	750,000	50,000	1,500,000		3,050,000	6,987,000
Marquette	400,000	100,000	200,000	100,000		800,000	150,000	20,000	80,000			250,000	1,050,000
Menominee	55,000	250,000				305,000	100,000	50,000	40,000	25,000		215,000	520,000
Midland	8,250,000		1,500,000			9,750,000	250,000	400,000	100,000	1,500,000		2,250,000	12,000,000
Mount Pleasant*	250,000	70,000	75,000	75,000		470,000	50,000	100,000		400,000		550,000	1,020,000
Muskegon*	1,550,000	500,000	100,000	100,000		2,250,000	100,000	100,000	50,000	800,000		1,050,000	3,300,000
Muskegon Heights	475,000	325,000		275,000		1,075,000	100,000			675,000		775,000	1,850,000
Niles	36,000	150,000	15,000	25,000		226,000	350,000	75,000				425,000	651,000
Owosso	2,500,000	200,000			100,000	2,800,000							2,800,000
Saginaw	3,375,000		500,000	1,000,000		4,875,000	2,000,000	7,000,000				9,000,000	13,875,000
St. Joseph	637,900	579,000	167,200	90,000	248,300	1,722,400	25,000					25,000	1,747,400
Sault Ste. Marie	721,130	282,570	292,700	150,000	216,960	1,663,360	171,000	454,996		933,000		1,558,996	3,222,356
Traverse City*	550,000	200,000	200,000	150,000	50,000	1,150,000	100,000	80,000	20,000	300,000		500,000	1,650,000
CITES OF OVER 2,500 BUT LESS THAN 10,000 POPULATION													
Alma	$[illegible]	$150,000	$ 75,000	$30,000	$10,000	$555,000	$50,000	$80,000	$15,000	$50,000		$195,000	$[illegible]
Belding	[illegible]	50,000	80,000	25,000		175,000	175,000	120,000		400,000		695,000	[illegible]
Bessemer	4,[illegible]		2,000	15,000	700	22,200	3,000	1,000		500		4,500	26,700
Big Rapids	155,000	125,000	25,000	40,000		345,000							345,000
Charlevoix	15,000	100,000	100,000	100,000	50,000	365,000	100,000	100,000	20,000			220,000	585,000
Charlotte	43,000		30,000			73,000		85,000	55,000			140,000	213,000
Cheboygan	17,000		30,000	50,000		97,000	150,000	60,000				210,000	307,000
Coldwater	60,000	450,000		231,000	92,000	833,000	100,000	200,000	25,000	50,000		375,000	1,208,000
Dowagiac	170,000			170,000		340,000		25,000	20,000	300,000		345,000	685,000
East Grand Rapids	10,000	50,000	2,000,000	50,000	10,000	2,120,000	200,000	50,000	25,000	150,000		425,000	2,545,000
Eaton Rapids	25,000	35,000		50,000		110,000		20,000				20,000	130,000
Essexville		50,000	100,000	45,000		195,000	100,000		50,000			150,000	345,000
Fenton	30,000	150,000	60,000	40,000		280,000	60,000	30,000	30,000	50,000		170,000	450,000
Fremont	25,000	50,000		100,000		175,000	50,000			25,000		75,000	250,000
Greenville	30,000	80,000	150,000	125,000		385,000	100,000	120,000	30,000	150,000		400,000	785,000
Hastings	13,800		21,000	20,000	3,000	57,800	10,000	10,000				20,000	77,800
Hillsdale	6,000		2,000	10,000		18,000	6,000		4,000			10,000	28,000
Howell	36,000	10,000	7,500	22,500		76,000	25,000		15,000	175,000		215,000	291,000
Iron Mountain	7,000	50,000	38,000	22,000		117,000	35,000	12,000	14,050	250,000		311,050	428,050
Iron River*	32,000		15,000	12,000		59,000		75,000		170,000		245,000	304,000
Lapeer*	15,000	75,000			50,000	140,000	150,000	50,000	50,000	350,000		600,000	740,000
Laurium ¹													
Ludington	780,050	90,000	103,400	100,000		1,073,450		26,000	50,000			76,000	1,149,450
Manistee	44,000	60,000	16,000	24,000		144,000	60,000		30,000	18,000		108,000	252,000
Manistique*	$150,000					$150,000	$138,957	$233,504	$23,046	$280,800		$676,307	$826,307
Marshall	5,000		$30,000	$15,000		50,000	140,000		40,000			180,000	230,000
Mount Morris	33,000	$51,800	8,000	3,000	$12,000	107,800						800,000	907,800
Munising	90,000	55,000	150,000	500,000	170,000	965,000	225,000	250,000	80,000	400,000		955,000	1,920,000
Negaunee		500,000	100,000			600,000	100,000					100,000	700,000
Newberry	8,000			15,000		23,000				100,000		100,000	123,000
Norway	8,700		5,000	3,000		16,700	5,000	7,500	1,500			14,000	30,700
Otsego	25,000	25,000	5,000	20,000		75,000	25,000	15,000	20,000			60,000	135,000
Petoskey	8,000	80,000	30,000	50,000		168,000	20,000	40,000	10,000			70,000	238,000
Plainwell*													
Portland*	15,000	100,000	25,000	75,000		215,000	50,000	100,000	150,000			300,000	515,000
Rogers City	20,000		6,000	30,000	5,000	61,000	45,000	20,000	25,000			90,000	151,000

St. Johns	47,000	60,000		90,000		197,000	20,000	160,000	15,000	222,000		417,000	614,000
St. Louis	90,000	10,000	20,000			120,000	150,000	50,000	75,000			275,000	395,000
South Haven	16,500	140,000	56,000	130,000		342,500	280,000	42,000	76,000	350,000		748,000	1,090,500
Springfield	30,[illegible]	80,000	60,000	257,000	5,000	432,000	350,000	160,000	40,000	350,000		900,000	1,332,000
Sturgis	50,[illegible]	75,000	100,000	100,000		325,000	75,000	100,000	25,000	250,000		450,000	775,000
Tecumseh	190,000	15,000	200,000	40,000	25,000	470,000	35,000	335,000	20,000	50,000		440,000	910,000
Trenton			600,000	200,000	70,000	870,000	580,000	450,000	100,000	1,250,000		2,380,000	3,250,000
Vassar	31,000	7,500	15,000	15,000		68,500	40,000	50,000	10,000			100,000	168,500
Wakefield	49,450	13,300		86,204		148,954	52,481	307,302		193,800	$24,308	577,891	726,845
Zeeland	75,000		200,000	20,000		295,000	35,000		30,000	40,000		105,000	400,000

CITIES OF LESS THAN 2,500 POPULATION

Almont*	$14,000	$15,000	$3,000	$3,000		$35,000	$15,000	$30,000	$10,000	$125,000		$180,000	$215,000
Armada	15,000			10,000	$10,000	35,000						270,000	305,000
Baraga	12,000		5,000	5,000		22,000	5,000	5,000		7,000		17,000	39,000
Berrien Springs	30,000	50,000	40,000	20,000	30,000	170,000	50,000	25,000	15,000	50,000		140,000	310,000
Blissfield	190,000		15,000	50,000	3,500	285,500	400,000	300,000	35,000	300,000		1,035,000	1,220,500
Bridgman						250,000						250,000	500,000
Bronson*	45,000	50,000	20,000	20,000		135,000	300,000	200,000		400,000		900,000	1,035,000
Brown City	22,000			6,000		28,000	5,000			100,000		105,000	133,000
Burr Oak						30,000							30,000
Byron						213,000						200,000	413,000
Calumet [1]													
Carson City	14,000	60,000		163,280		237,280	200,000			70,000		270,000	507,280
Centreville	8,000	1,000		25,000	26,000	60,000							60,000
Coloma*	15,000	10,000	4,000	1,000		30,000	10,000	2,000		40,000		52,000	82,000
Columbiaville		5,000	2,000	1,500		8,500	15,000	10,000		20,000		45,000	53,500
Croswell	21,000			3,000		24,000	50,000	75,000	50,000	200,000		375,000	399,000
Crystal Falls	81,000	25,000	6,000	8,000		120,000	25,000	25,000	5,000			55,000	175,000
Decatur	14,500	1,000	5,000	15,000	4,000	39,500	280,000	30,000	24,000	40,000		374,000	413,500
DeWitt	45,000	10,000	30,000	40,000		125,000	50,000	25,000	25,000	100,000		200,000	325,000
Dundee*	2,000	50,000	10,000			62,000						385,000	447,000
Edmore	2,850	13,206	52,324	15,097	16,469	99,946	5,000	5,000				10,000	109,946
Elberta	15,000	10,000				25,000			10,000	50,000		60,000	85,000
Evart*	12,000	50,000	12,000	3,000		77,000	5,000	10,000	1,000	75,000		91,000	168,000
Farwell				15,000	7,500	22,500						400,000	422,500
Fennville	16,000		110,000	60,000	10,000	196,000						300,000	496,000
Flushing*	25,000	90,000	25,000	50,000		190,000	100,000	160,000	80,000	250,000		590,000	780,000
Fruitport						150,000						350,000	500,000
Galesburg	16,000	50,000	20,000	40,000	10,000	136,000	200,000	40,000		125,000		365,000	501,000
Grand Blanc	2,500			11,000		13,500	325,000			125,000		450,000	463,500
Harbor Beach	233,176		82,835	74,371	19,000	409,382	60,000	100,000		257,860	40,000	457,860	867,242
Harrison	12,000		10,000	18,000		40,000							40,000
Hart	25,000		50,000	200,000		275,000	25,000	75,000		125,000		225,000	500,000
Hesperia	17,000			79,200		96,200						375,000	471,200
Homer	21,000			4,000		25,000	4,000		1,000			5,000	30,000
Howard City	53,000		20,000	15,000		88,000	40,000	15,000		20,000		75,000	163,000
Hudsonville	3,652	700	7,000			11,352							11,352
Imlay City*	141,000	200,000	10,000	50,000	16,000	417,000	50,000	80,000	200,000	60,000		390,000	807,000
Jonesville												500,000	500,000
Kalkaska	17,500		12,000	18,000		47,500						400,000	447,500
Lake City						260,000						365,000	625,000
Lake Linden [1]													
L'Anse*	158,000	40,000	58,000	50,000	15,000	321,000						250,000	571,000
Lawton		60,000	30,000	30,000		120,000	30,000		7,000			37,000	157,000
Linden			20,000	12,000		32,000	225,000	80,000		155,000		460,000	492,000
Lowell	22,000		10,000	96,000	8,000	136,000	118,000	25,000	5,000	65,000		213,000	349,000
Mackinaw City	17,500	35,000	25,000	15,000		92,500							92,500
Mancelona	4,950		1,000	10,000	1,500	17,450							17,450
Manton	5,000	40,000		7,500	5,000	57,500							57,500
Maple Rapids	5,000		2,000	20,000		27,000							27,000
Marlette*	15,000		5,000	15,000		35,000	50,000	50,000	25,000	250,000		375,000	410,000
Mayville	7,500	2,000	1,000	5,000		15,500		21,000		200,000		221,000	236,500
Nashville	21,500	34,000	10,000	8,000		73,500	8,000	12,000	20,000	98,500		138,500	212,000
Newaygo	25,500	25,000		66,000	1,500	118,000	30,000	25,000		140,000		195,000	313,000
North Branch [1]													
Northport				5,000		5,000							5,000
Olivet	20,000	35,000				55,000	130,650	12,700	21,690	40,400	26,044	231,484	286,484
Onaway	11,500	5,000				16,500							16,500
Ontonagon*	53,000	150,000	70,000	300,000	25,000	598,000	55,000	63,000		125,000		243,000	841,000
Parma	32,000	27,000	2,500	61,714	3,668	126,882	37,744		39,050	99,200	1,006	167,000	293,882
Pentwater	10,000	25,000		20,000		55,000	8,000	4,000	3,000	200		15,200	70,200
Potterville	10,000			10,000		20,000						100,000	120,000

See footnotes at end of table, p. 131.

Urban units reporting (excluding southern Michigan)—Continued

CITIES OF LESS THAN 25,000 POPULATION—Continued

Municipality	Waterworks expansion						Sewage works expansion						
	Production facilities	Storage	Transmission mains	Distribution mains	Other miscellaneous	Total water	Lateral sewers	Internal sewers	Pumping	Treatment	Other miscellaneous	Total sewage	Grand total
Powers	$9,000	$30,000		$29,000	$5,000	$73,000						$175,228	$248,228
Roscommon*					5,000	5,000						235,000	240,000
St. Charles	10,000		$20,000	30,000		60,000	$200,000	$50,000	$50,000	$200,000		500,000	560,000
Saranac	7,000		3,000		2,000	12,000	4,500	1,000		5,000		10,500	22,500
Saugatuck*	35,000	50,000		60,000		145,000				500,000		500,000	645,000
Scottville	35,000		35,000	10,000		80,000	50,000	75,000				125,000	205,000
Sebewaing	52,000					52,000	180,000	50,000	50,000	270,000		550,000	602,000
Shepherd	20,000	3,000	3,000	5,000		31,000						150,000	181,000
Sheridan	40,000		5,000	10,000		55,000							55,000
South Lyon[1]													
Stambaugh*	25,000					25,000				160,000		160,000	185,000
Standish	35,000		65,000			100,000		30,000	10,000	160,000		200,000	300,000
Stephenson		1,400	15,000			16,400	15,000			74,000		89,000	105,400
Union City	11,000		2,500	10,000		23,500							23,500
Unionville			5,000			5,000	7,000					7,000	12,000
Vicksburg	14,000		1,000	67,150	5,000	87,150	30,000		30,000	175,000		235,000	322,150
Wayland	30,000	50,000		160,000		240,000	300,000			100,000		400,000	640,000
Webberville						140,000		20,000				20,000	160,000
Whitehall	25,000	70,000		140,000		235,000	7,500	150,000	24,000			181,500	416,500
TOWNSHIPS													
BAY COUNTY													
Bangor Township			$400,000	$150,000		$550,000	$600,000	$1,100,000	$200,000			$1,900,000	$2,450,000
Monitor Township						2,000,000						7,600,000	9,600,000
Portsmouth Township[1]													
BERRIEN COUNTY													
Benton Township	$34,750	$239,000		1,389,163	$54,500	1,717,413	1,382,773		216,000			1,598,773	3,316,186
Chikaming Township	95,000		40,000	120,000	35,000	290,000	150,000	80,000	60,000	$75,000		365,000	655,000
Coloma Township							125,000		35,000	66,000		226,000	226,000
CALHOUN COUNTY													
Battle Creek Township	14,700	95,000	67,300	275,000	48,000	500,000	1,992,000	583,000	40,000	385,000		3,000,000	3,500,000
Bedford Township	75,000	30,000	40,000	30,000	20,000	195,000	30,000	30,000	10,000	200,000		270,000	465,000
GENESEE COUNTY													
Flint Township							750,000	400,000	40,000	900,000		2,090,000	2,090,000
Mount Morris Township	650,000		400,000	750,000		1,800,000	350,000	150,000	100,000	1,000,000		1,600,000	3,400,000
Burton Township	320,000	300,000	100,000	300,000		1,020,000	2,000,000	650,000	350,000	1,000,000		4,000,000	5,020,000
Genesee Township							500,000	150,000	30,000	750,000		1,430,000	1,430,000
INGHAM COUNTY													
Lansing Township	100,000		8,000	62,000	5,000	175,000							175,000
Delhi Township	20,000	100,000	250,000	100,000		470,000	150,000	100,000	25,000	200,000		475,000	945,000
Meridian Township	261,000	480,500	200,000	100,000	20,000	961,500	1,300,000	263,000	137,000	750,000		2,450,000	3,411,500
JACKSON COUNTY													
Summit Township						1,500,000						2,500,000	4,000,000
KENT COUNTY													
Paris Township	290,000	800,000		750,000		1,840,000						2,000,000	3,840,000
ROSCOMMON COUNTY													
Roscommon Township	80,000	50,000		300,000		430,000	600,000		100,000	75,000		775,000	1,205,000

SAGINAW COUNTY													
Buena Vista Township				50,000		50,000				1,025,000		1,025,000	1,075,000
Saginaw Tonwship	8,000	30,000		400,000		438,000	500,000	1,500,000	5,000	60,000		2,065,000	2,503,000
Zilwaukee Township	71,000	6,000	15,000	50,000		142,000	350,000	300,000	50,000	100,000		800,000	942,000
Carrollton Township	30,000			150,000		180,000	200,000					200,000	380,000
Beecher Metropolitan District	30,000	150,000	12,000	35,000		227,000	35,000	15,000	90,000			140,000	367,000
Saginaw Mid. Water Supply	2,000,000		12,000,000			14,000,000							14,000,000

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[1] No anticipated expenditures reported.

[2] No information supplied.

Exhibit No. 5

Where Do We Get Our Water and How Much Do We Have?

(A paper presented at the industrial water conservation course, University of Michigan, by Norman Billings, Michigan Water Resources Commission, June 8, 1959)

Your program committee's assignment of this topic to me is taken as a very great compliment and as a distinct responsibility, seeking, as I am sure it does, the presentation of a clear but concise picture of the water resource situation and its practical implications to industry. You are interested, I believe, not in vague generalization on the one hand nor in a mass of technical detail on the other but, rather, in the development of a working foundation upon which to base policy decisions and action programs.

To lay the footings for such a foundation we should first take account of certain special characteristics of water as a resource, the implications of which pervade its entire relation to our economy.

First among these is quantity. The volumes dealt with, both as an asset and as an enemy, are so enormous as to involve an entirely different set of principles than we apply to other resources. The quantity factor imposes severe limits on transportation and storage. In a very large measure, this makes industry dependent upon local resources and vulnerable to injury from their impairment. And, what is directly to the point, it strongly emphasizes the propriety of active and continuing interest by industrial management in the well-being of those local resources. This interest is warranted whether industry deals with the resource directly or through municipal facilities.

Secondly, water resources are notoriously variable, particularly in the aboveground phases of the so-called hydrologic cycle but also, to an important degree, in the underground phases as well. Water resources vary in quantity and quality from place to place, and also from season to season at any given place. Furthermore, these variations result not only from natural causes but may be manmade as well. Therefore we are forced to concern ourselves with the occurrence of statistically prospective extremes, both of scarcity and of damaging superabundance. And it is not enough for us to analyze the frequencies of floods and drought flows of various intensities or the safe yield of wells. We must also consider how the natural variations of water may be even further intensified by the actions of other people.

Thirdly, water is complex, and is steadily becoming more complex, in the ways that it involves our interests. The same resource must, in many cases, serve a great number and variety of purposes at widespread locations. It can also be a nuisance to some and an asset to others. Accordingly, a considerable number of people may be interested in its condition and management and each may desire a somewhat different result. These results may be potentially compatible or they may be grossly incompatible. The point is that, in any case, the resolution of water problems is coming more and more to necessitate involvement of many people and many interests. This involvement can take place either in a spirit of cooperation and good will around the conference table or of conflict and antagonism in the courts of law.

Finally, among these fundamental peculiarities of water as a resource, is its obscurity of occurrence and behavior. This is particularly true of underground waters, but even in rainfall, in the flow of streams, in the depths of lakes, and in other aspects, water escapes our full understanding and appreciation. Unfortunately, what we can see of it is so obvious and impressive that it encourages a sense of familiarity and, too often, of contempt. Thus we are led into basing developments on water conditions as they seem to be, rather than as they are. And we are apathetic or even impatient toward investing the money and time that it takes to replace complacent supposition with actual knowledge, through tedious surveys and investigations.

THE HYDROLOGIC CYCLE

Water is essentially a dynamic resource. It is always moving from its origin as intermittent precipitation on the surface of the land toward its destination, which is the atmosphere or the ocean. Even underground, the fresh waters are moving, although the velocity is slower there. The sequence of events through which water moves on this unending journey is commonly known as the hydrologic cycle. It is appropriate to our present interest that we briefly review the basic elements of this cycle as a unit.

Our water "bank" is sporadically replenished by precipitation, occurring mainly as rain or snow. The average annual precipitation for the State as a whole is about 31 inches of water. This figure may vary substantially with locality and season. In the States to the south of us, at least, there appears to be a tendency for wet years and dry years to come in "batches." We do not know whether this is true of Michigan or whether the occurrence of several wet or dry years in a row is merely in accordance with the statistical laws of chance. We have no information that would point to a cyclical pattern of wet- and dry-year sequences nor in anyway support the prediction of future wet or dry years beyond the long-range forecasts of the U.S. Weather Bureau. We know of no long-term trends toward greater or lesser precipitation. In fact we plotted the annual State averages for the period of record a few years ago and found them to define a horizontal line, as nearly as we could judge.

In the absence of predictable cycles or occurrence patterns, anticipating future hydrologic events must be based on the statistical laws of chance which, of course, will tell us "how often" but not "when."

Of the water that precipitates annually as snow or rain or other measurable forms, part sinks into the ground and part flows across the surface of the ground to lakes, streams, or marshes. A large portion of the precipitation never reaches the streams because it is evaporated into the atmosphere before it gets there. This evaporation takes place from the wetted surfaces of leaves and soil, from lakes and other surface waters, from snow and ice, from the depths of the soil and from the underground water surface itself, and probably most importantly, through the life processes of vegetation. How much of the rain or snow evaporates in any locality depends on many factors that will be mentioned later but the net loss varies from more than 100 percent of annual precipitation under the worst conditions to somewhat less than 50 percent under the best conditions. The average loss, as shown by flow of the major rivers, appears to be about two-thirds of precipitation. Most of the rainfall that occurs during the growing season of vegetation is lost through evaporation.

Of the portion of precipitation that seeps into the ground a large part is taken up by vegetation roots. That which penetrates beyond reach of the roots eventually reaches the water table, which is the surface of the saturated zone wherein all openings between earth particles are full of water. From this zone, water is always overflowing into streams, lakes, marshes, springs, or other surface outlets. It is important that we recognize these surface-water features as outlets for underground water accumulations—not inlets for ground-water replenishment. Lakes and streams don't water the land in this part of the country, but drain it.

In summary, the hydrologic cycle is a complex of continuing depletion of the water resource by drainage and evaporation, and of intermittent replenishment by precipitation. There is great variation in the intensity and extent of these events from place to place and from time to time.

This variation is very important to industry, which needs to know how much dependence it may place on the resource. Identifying that dependability requires the collection of great amounts of data, appraising the complex of physical influences involved, and statistically analyzing them as to occurrence frequencies.

Data collection on streamflows, underground water, and inland lake levels is carried on under a cooperative cost-sharing program with the U.S. Geological Survey. State agency budget requests for expansion of this program are not exactly "best seller" literature in the legislative appropriation committees.

Hydrological analysis of data shows what happens under various physical conditions. Statistical analysis shows how often it happens—how many years out of a decade you can expect a given minimum streamflow of a given duration to occur. The Water Resources Commission, through the School of Public Health, University of Michigan, is now completing a statistical analysis of the frequencies of low flows of all gaged Michigan streams. The results of this analysis should be of great interest to water-using industry.

GROUND WATER

The underground reservoirs of fresh water that supply all of our wells are just saturated layers of sand and gravel or of permeable rock. All the water in them originated as rain or snowmelt that has percolated down through the soil and underlying earth materials and has filled the openings between the earth particles or the openings in the rock. It is the residue of rain and snow that remains after surface runoff and evaporation. Intermittent replenishment of these reservoirs (occurring mainly in the spring) is known as recharge. The volume of annual recharge that occurs in any area depends upon the stringencies of the gantlet the water must run in moving down from the land surface to the deep storage zones. Overland runoff, at the expense of ground water recharge, is encouraged by tight soils, steep slopes, scanty vegetation, and high intensity of rainfall or snowmelt. Fine-textured soils and subsoils detain more of the infiltered water within reach of consumption by plant roots, also at the expense of ground-water recharge, than do coarse materials. Under the most favorable recharge conditions such as the sandy plains around the Manistee River headwaters, several inches may reach the underground reservoirs annually. Under poor conditions it may be an inch or less.

Where heavy pumping is taking place through numerous and widespread wells it may be important to ascertain how many inches of water the annual recharge represents. Generally, however, in the eastern part of the Nation at least, whether your industrial wells yield water copiously, indifferently, or grudgingly is controlled more by the local capacity of reservoir materials to transmit their water content to wells than by the actual volume of water that is contained in those reservoirs or by the extent of their seasonal recharge. That capacity to transmit water depends on how thick and coarsely porous the reservoir strata are in the immediate vicinity of the well and how continuous (and interconnected with other strata) they are within the few-hundred-acre tract surrounding the well.

The question raised in this paper's title, "How much water have we?" then resolves itself, as regards ground water, into the specific question, "How much sand, gravel, and permeable rock have we that is filled with water?"

If we could leave the question even in that modified state, its answer would still be "Plenty." Obviously we have got to think in terms of definite locations—where you already have a factory or where you might be thinking of establishing one.

The upper portions of the earth of Michigan consist of material that was brought in and deposited by geologically recent continental glaciers which flowed southward from certain Canadian areas of snow accumulation. This material, known as glacial drift, varies in thickness from a few inches to more than a thousand feet. It consists of layers and lenses of clay, silt, sand, and gravel or mixtures of these materials. The general thickness of the drift for each locality is fairly well known—better in some places than in others. The broad-scale or regional character of the drift is also fairly well known but the local details are not, except in scattered locations. Preparation of accurate maps and reports of glacial drift geology can proceed only on the basis of information obtained in well drilling. Information obtained from water-well drilling does not have to be filed (except for public-water-supply wells). We estimate that more than a million wells have been drilled in the State, but records of only a few thousand are on file with the State. It has been estimated that 20,000-odd water wells are drilled per year, but the records of only a few hundred are filed annually.

Under the glacial drift are sequences of rock layers and formations. The distribution, character, and thicknesses of these layers and formations is fairly well known, principally from the records of oil and gas well drilling, which do have to be filed with the State. Local details are not so well known, but bedrock geology is more uniform and consistent than glacial drift geology and rock conditions at a particular location can often be predicted quite reliably from the records of nearby oil and gas wells.

The best and most complete information on local geology will only give you general indications as to your chances for getting water from the ground at a given site. It does not show how much you can hope to pump from any well or group of wells.

Let me emphasize, as a major point in this talk, that the only way to find out how much water you can pump from the ground at any location is to run so-called aquifer performance tests. Those tests consist of pumping at carefully regulated rates from wells at the location in question, observing the resultant "drawdown" of water level in appropriately located pilot wells, and analyzing the findings by application of special formulae.

If wells do not already exist from which the water can be pumped and in which water-level change can be measured, the only way out is to drill them, and to drill them to the depths and construction specifications requisite for the test.

It may pay an industry that is faced with an extensive or protracted program of ground-water development to arrange for special training of certain of its staff engineers in the principles and techniques of conducting aquifer performance tests. Otherwise the job should be turned over the consulting engineers, geologists, or geo-physicists who are qualified to handle it.

Such tests, by the way, will reveal not only the potential ground-water yield at a given location but also the effect of any particular pumping rate on neighboring wells. Although the legal implications of injury done to others by pumping from wells are not at all clear, as will be discussed later, none of us is anxious to antagonize his neighbors. Tests whose results indicated prospective drying up of nearby residential wells would certainly be important to industrial management in making its plans for future water supply. Such findings were importantly involved in the decision of one large Michigan city to develop surface-water sources instead of expanding its ground-water use.

Now, the influence of strata character upon the yield of a well is often most critical in the immediate vicinity of the well. This is true because of the progressively greater velocities at which the water must move as it approaches the well through progressively diminishing circumferences. Friction losses increase drastically with velocity.

Construction techniques to reduce this friction in the "bottleneck" area around the well are accordingly sometimes very important for they can increase well yields by as much as several hundred percent. Therefore, selecting and applying appropriate techniques should be given careful attention. This is a job for the hydrologist—either your own or a private consultant—and a skilled and versatile well driller.

To mention a few of the techniques, there are (1) development of the conventional tubular well by surging and backwashing through a screen of carefully selected opening size; (2) the installation of sand or gravel packs inside removable, oversize casings; (3) the extension of horizontal feeder screens from vertical caissons; (4) buried tile fields for streamside gravels; (5) batteries of small-diameter suction wells for shallow, thin aquifers; and (6) acidizing, blasting, or hydraulic fracturing of rock wells.

Production of water from the ground through wells is largely at the ultimate expense of streamflow. That is to say, if you don't pump it out of the underground formations it is eventually going to find its way into surface streams through springs and seeps.

Where heavy pumping takes place from wells that are close to small streams and that tap underground reservoirs which are intimately connected with those streams they may appreciably diminish the local streamflow. That diminishment may or may not be important. At how many gallons per minute average do you plan to pump? How many gallons per minute does the stream flow during periods of drought? And where will the water be returned to the stream after use?

Where wells are not close to streams and where the formations they tap are in less than perfect hydraulic connection with the streams the effect of their pumping tends to be widely disposed.

Pumping water from wells produces a local cone of depression in the water table or in the ground-water pressure surface. The dimensions of this depression vary from the tiny dimple of a suburban household well to the great funnel, dozens of feet deep and miles across, of some municipal-industrial well systems.

The harder you pump from any well, the deeper this "drawdown" cone becomes, and the most you can pump from any well is the rate which pulls the tip of the cone down to the top of the screen; or, in an unscreened well, down to the top of the pump at its lowest possible setting. Just what this rate is, in gallons per minute, at any well depends on the local underground conditions, as we said earlier. Wells whose drawdown cones overlap interfere with each other's production and the closer they are together the greater this interference is.

It is not the purpose of this report to examine the details of factors that limit the yield capacity of underground reservoirs. We wish to emphasize that such capacity can be ascertained by running aquifer performance tests and that it relates to the mechanical ability of the aquifer materials to transmit water rather than to the actual water content of the aquifer.

The latter point bears upon the possibilities for artificial replenishment of ground water. Except in the few areas of most intensive and concentrated pumping, there has been no significant depletion of underground water in Michigan. The limit of a local ground-water reservoir to yield water is being approached in some cases and there has been reduction in per-well yields because of their being drilled too close to each other. Some wells are inducing infiltration from streams and lakes. At Kalamazoo, stream waters are being led across one of the municipal well fields to encourage infiltration. This kind of gravity infiltration may find extensive future application where the materials between ground surface and underground reservoir will readily transmit the water. In many places, the water-producing formation is overlain with tight shales or clays. At those places, pressure-injection wells would be necessary to accomplish artificial replenishment. No such project should be undertaken without careful study of the situation and scrupulous adherence to public-health specifications as to construction and water treatment.

SURFACE WATER

The other major source of water for industrial purposes is lakes and streams. This source is directly utilized in Michigan for industrial supply to a relatively limited extent because of the general availability of higher quality ground water or municipal water. In areas where groundwater supply is deficient or industrial requirements are excessively large, the development of surface supplies may become increasingly necessary.

However, streams and lakes are almost universally required for the assimilation and removal of industrial liquid wastes, either directly, through plant sewers, or indirectly through a municipal sewer system.

The following discussion relates primarily to that use. Most interior streams discharge quite respectable quantities of water per square mile of drainage area on an annual average basis. However, flows of streams in the southern part of the State and many other localities fluctuate quite drastically from season to season. Waste discharges of most industries do not so fluctuate, with the result that waste concentrations within the receiving waters vary somewhat inversely with streamflow. A waste discharge that would be fully assimilated by a stream in June for example, may create intolerable pollution conditions in August, when the streamflow has dwindled to a mere fraction of its early summer volume. This bottleneck in the capacities of streams to accommodate industrial wastes constitutes the most critical factor in the ultimate limits of waste-producing industiral expansion at the large majority of interior locations. It should be accorded the most earnest attention in the planning of any interior industrial development. That attention must be eminently realistic and should scrupulously avoid optimism as to future conditions that is not clearly supported by records of past stream behavior. Neglect of this basic requirement can lead to the most unhappy results. Certain possibilities do exist for artificial improvement of streamflows during the bottleneck period but they are beset with many difficulties, the solution of which should predate industrial developments depending upon them.

Information indicative of minimum flow-conditions to be expected at any location is found in U.S. Geological Survey Water Supply Papers and in the results of our statistical analysis that was mentioned earlier. We must emphasize, however, the word "indicative," for the streamgaging stations from which the data are compiled are by no means universally distributed. Appraising the streamflow potential of ungaged streams or at locations remote from gaging stations on gaged streams involves the transposition of gaging data as modified by expert evaluation of the hydrologic character of the stream under investigation. This is a job for the professional hydrologist and thoroughly warrants his employment. To emphasize and illustrate this point let us quote just a few minimum flows.

[Cubic feet per second]

River	Average flow	Lowest 7 consecutive days
St. Joseph, at Mottville	1,548	309
Kalamazoo, at Kalamazoo	876	217
Grand River, at Lansing	868	45
Tittabawassee, at Midland	1,558	126
Flint, at Flint	569	23
Clinton, at Mount Clemens	497	28
Raisin, at Monroe	731	18

These minima are not directly comparable because the lengths of record for the various streams are not all the same.

As we said these flows are, under some circumstances, susceptible of certain improvements, notably by the release of artificially developed upstream storage during the critical periods. As some of you know, this potentiality was recently investigated on the upper Kalamazoo River as a possible means for alleviation of drought flow conditions along the industrialized lower reaches. Sufficient reservoir storage to appreciably increase the low flow was found. However, the estimated cost of its acquisition and development was found to exceed the cost of effectuating the still possible improvements in waste treatment that would produce an equal result in the water quality of the lower river. Eventually of course, you do reach a point where further improvement of waste treatment is economically impossible. Then the only remaining means by which further waste-producing industrial development can be accommodated is through the physical increase of minimum streamflow. Theoretically, possibilities along this line are tremendous and are represented by the long-term average rate of discharge of the stream at the location under study. However, computation of the reservoir storage space required for effectuating increase in minimum flow quickly shows this theoretical potential to be completely unattainable. Beyond the relatively small storage space that can be provided by the best reservoir sites, additional increments of storage provided by progressively less desirable sites come at increasingly high costs. The economic problem is compounded by the diminishing returns per acre-foot of storage in cubic feet per second of assured stream flow. For example, in our study of storage requirements for improving minimum flow of the Huron River at Ann Arbor where the average flow is 433 cfs, 3,600 acre-feet of stored water would have assured a minimum flow of 50 cfs during the period of record instead of the 20-odd cfs that actually occurred. This is about 120-acre-feet per cfs improvement. To raise the minimum flow to 70 cfs (an increment of 20 cfs) would have taken an additional 3,200 acre-feet or 160 acre-feet per cfs. The next 20 cfs would have required an additional 5,800 acre-feet, or 290 acre-feet per cfs.

Most sites that are suitable for reservoir development are already utilized for other purposes, some of them quite intensively, and the trend is toward ever greater expansion of values that would have to be paid for in purchasing these sites. Nor is cost the only deterrent to reservoir-site acquisition. Public reaction to the uprooting of established values is apt to be strongly unfavorable, especially where homes and farms are involved. Keen appreciation of human interests will be essential to the realization of the singular water-conservation potentialities offered by reservoir storage.

No analysis of water conservation should omit discussion of and tribute to the land-management principles that are coming more and more to be adopted and advocated by foward-looking representatives of all interests. Soil conservation, reforestation, grassland farming and a host of specific land-use measures devoted to conservation and best use of the land react quite generally to the benefit of water quality and, in some ways, to that of water quantity. The dedicated and capable proponents of these land-management principles in Government agencies and private interests are entitled to our gratitude and respect. They are poorly served by the hysterical fringe of public opinion which would identify their laudable efforts and accomplishments as magic cure-alls for our vast complex of water resource problems.

RAINWATER

A third source of water for industrial use that has recently gotten some attention in the literature is rainwater from factory roofs and paved areas. This uses the old farm-cistern principle, which some of us recall, but on a larger scale. Its suitability for any given purpose depends on the quantity, temperature, and purity of water needed for that purpose, the size of catchment areas available, and the costs of catching and storing it. The quantity of water that could be obtained in this fashion probably represents a large percentage of total precipitation on the catchment area. Whether it would be 75 or 90 percent we do not know. It is my guess and that of others I have talked with, that the figure would be in that general magnitude. However, computation of the necessary catchment area and storage volume should take proper account of rainfall variations so that an appropriate safety factor can be provided. If pumping the cistern, dry merely means that you turn to an alternative source that's one thing. If it means you shut down the plant, that's another.

Rainwater storage would normally be in outdoor open pools because covered storage would be too expensive. That implies the prospect of fairly heavy evaporation losses. Research on antievaporant chemicals, particularly the solid alcohols such as hexadecanol, is showing some promise.

At most places in Michigan, soils are so porous that rainwater storage pools would have to be lined with impervious material to prevent excessive seepage losses. A wide range of such materials may have application. Among them are concrete, asphalt, and polyethylene film. Bentonite, clay, earth compaction, and earth cement are also used for reservoir and canal lining under some circumstances.

MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT

Another potential source of industrial water that has recently come into some prominence is the effluent of municipal sewage-disposal plants. So far, interest in this source originates mainly in the West where water availability differs considerably from that of the East and quality requirements can be compromised somewhat in favor of quantity. The adaptability of this source to specific industrial needs is largely a question of chemistry, engineering, and finance. Quantitatively, the steady supply available, even in medium-sized towns, is quite substantial. Is it dependably adequate? Is its quality suitable to your needs? What engineering would be involved in getting it from the sewage-disposal plant to your factory? How much will the project cost? Although these questions imply some study, they are straightforward and answerable by technical staff or consultants. Note should be taken of the prospect for continued maintenance by the sewage-disposal plant of satisfactory effluent quality. Experience has shown that there tends to be a lapse between the time when overloading begins to produce a degraded effluent and the time when improvements are made in treatment facilities to correct that deficiency. Note should also be taken of the responsibility assumed by users of the effluent with regard to its ultimate disposal. If, after serving its industrial use, the water is to be returned to the municipal sewer systems, its treatment before discharge to the waters of the State is up to the municipality. But an industry discharging its wastes directly to streams, lakes, or underground reservoirs is held accountable for their pollutional effect regardless of whether the water was pure or not when it came to the industry.

At least that is the case in Michigan. And even if the effluent is satisfactory for discharge into the stream at the sewage-plant site, and even if no impurities are added to it by the industrial use, its discharge to another stream could cause pollution and therefore be unlawful.

LEGAL PROBLEMS

Along with the physical problems of water we are increasingly encountering legal problems, which can be as devastating to water use and management programs as actual water shortages, if not more so.

Most uses of water in Michigan and other Midwestern States is governed by common law instead of by statute. The common law accords to each owner of property that abuts on a lake or stream the right to use their waters as he sees fit. He must not, however, unreasonably interfere with the similar rights of other such owners (riparians) or with the public right of navigation on streams that meet the test of navigability. Whether or not a particular use is reasonable is for the courts to decide. The common law accords to an owner of land the right to take water from wells thereon for beneficial purposes. How much he can take and for what purposes, to the injury of another, is not clear from the few Michigan Supreme Court decisions that deal with ground-water conflicts.

The common law has operated with reasonable and possibly even notable efficiency to date. How long it can continue to do so is subject to question. Two deficiencies in it are apparent. It settles issues after they arise instead of before, and it does not cover certain uses that are becoming very important, such as diversion.

By diversion is meant the permanent removal of water from a lake or stream. By far, the greatest diversion and one that promises to become much greater is pumping water from lakes and streams to irrigate farm crops. (Irrigation of municipal parks, cemeteries, and lawns may use more water than farm-crop irrigation but most of this water is taken from wells or the Great Lakes.) We imply no lack of sympathy with the farmer's need for water in singling him out as the major diverter. However, we tell him as we are telling you that continued encroachment onto the low flows of streams would mean trouble ahead for everyone concerned. In the high flows, on the other hand, there is a very great potential for storage in farm-size ponds for summer use.

Statutory law has been enacted in Michigan and other States to govern the use of water for waste disposal. The Michigan statute does no violence to the basic principle of the common law but merely provides for administrative identification of unreasonable use and for its prevention or abatement.

We firmly believe that any future legislation on other facets of water rights must be similarly in harmony with the common law, upon which all of Michigan's vast water-using economy has been founded. Any rupture of the basic reasonable-use principle could open the way for wholesale destruction of public and private equities in water use, through power politics and shortsighted exploitation. All of Michigan's water uses are based upon some minimum dependability of the resource as provided by nature and as limited artifically only by the reasonable use by others. The cottage on a lake, the industry on the riverbank, the farm or suburban home with its well, in short every water-using entity is most gravely dependent on the security of the resource from usurpation by some more powerful entity. Perhaps industry could entertain some confidence as to the prospect of its success in a no-holds-barred battle for water rights, but which industry? The law permits condemnation of private property by governmental units but only for public purposes. Should "public purposes" ever be stretched to cover private developments, no matter how colossal, where, thereafter, can another rampart be erected?

It behooves industry to scrutinize very carefully all proposals for water-rights legislation and to maintain a broad and long-range view in appraising the soundness of such proposals. Nor is the industrial interest met by merely reacting to the ideas of others. Why shouldn't industry as a major water user seek active participation with other water interests in the timely development of mutually beneficial legislation? In any case, however, cognizance should be taken of the fact that there are no sharp lines of demarcation among industrial, recreational, agricultural, and municipal water interests. All overlap and intermesh, and the injuries or benefits to any one of them tend to be shared by all the others. With water, perhaps more than with any other resource, we prosper or suffer as a people, rather than as separate and independent groups.

Note may properly be taken of the fact that so far, agricultural interests have led in efforts to identify and effectuate sound principles of water-rights legislation. From our considerable contact with these efforts we are highly impressed with their objectivity and with the repeatedly demonstrated recognition, by rank-and-file farmers as well as by farm organization and agency leaders, that water is a community resource. We strongly feel that this attitude is an indispensable constituent of the foundation upon which to erect statutory water-rights law. Any division into armed camps of special interests would not only be fallacious in its assumption of self-sufficiency but could seriously hamper if not cripple the materialization of mutually advantageous legislation. The reality of this danger is attested by recent and current conflicts in other States.

Two other fields seem particularly appropriate for industrial participation in water resource matters. They are factfinding and planning. Some industries, especially among the hydroelectric power companies and iron-mining companies are now participating or have participated financially in the gaging of streamflow and inland lake levels and the investigation of underground water conditions. Because future water resource management and use depends so critically on adequate knowledge about the resource, further expansion in industrial support of the water factfinding program, consultative, moral, and financial is recommended. Similar support of efforts by area planning commissions to anticipate and revolve water resource problems on a coordinated basis is recommended. The passive, "wait and see" policy is poorly compatible with the accelerating speed at which modern water resource developments are taking place. By the time we can clearly see what is going wrong, its correction tends to be considerably more difficult and costly, if indeed, it is then possible at all.

SOURCES OF INFORMATION

We have already mentioned the U.S. Geological Survey Water Supply Papers as the main source of information on streamflow. These papers, published annually, contain data on daily flow of streams at all the Survey's 150-odd stream-gaging stations in the State. Data on groundwater levels at wells throughout the State being measured by the USGS are also published in Water Supply Papers. These may be obtained from the Superintendent of Documents in Washington or consulted in the office of the U.S. Geological Survey, the Water Resources Commission, the Geological Survey Division of the Department of Conservation, or in the university libraries.

The chief source of information on underground geology and water is the Geological Survey Division of the Department of Conservation, which is the repository for all available well-drilling records and which carries on special studies, both through its own facilities and in cooperation with the U.S. Geological Survey.

Data on precipitation are found in the Climatological Summary and other publications of the U.S. Weather Bureau, which may be obtained from the Superintendent of Documents or consulted in the above-mentioned offices and libraries.

Water-quality data may be obtained from the Mining Departments of Health and Conservation, the Water Resources Commission, and the U.S. Geological Survey. Special studies of local streamflow and lake levels have been made by the department of conservation and the water resources commission.

The latter agency is the main source of information on water pollution control. It has made detailed studies of water uses and condition in several major river basins and of the statewide irrigation-water usage.

All these agencies maintain close and continuous working relations with each other and a request for information to any one of them will promptly be referred to the proper recipient.

Professional and popular periodicals are replete with articles covering the whole range of water resource matters.

We suggest the same careful judgment in the acceptance and use of hydrological literature as is appropriate for any other complex science. Competent hydrological assistance, either from members of your own staffs or from private consultants, is indispensable in the identifying and solving of water resource problems.

EXHIBIT NO. 11

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959

Key to pollution status:

- A—Control adequate.
- B—Control provided—adequacy undetermined.
- C—Need for control undetermined.
- D—Control facilities available—protection found unreliable.
- E—Municipal treatment facilities utilized—industrial overload.
- F—Existing control inadequate or incomplete.
- G—No control.

Key to project status:

- c—Construction underway.
- p—Plans being prepared.
- s—Studies underway.

Industry	Location	Public waters affected	Industry rating
Abitibi Corp	Alpena	Thunder Bay	A
Allied Chemical & Dye Corp.:			
Barrett Division	Detroit	Rouge River	A
General Chemicals Division.	River Rouge	do	A
Semet Solvay Division	Detroit	Detroit River	A
Solvay Process Division	do	Rouge River	A
Allied Paper Corp.:			
Monarch Division (operations suspended).	Kalamazoo	Portage Creek	
Solids			B
Oxygen-demand wastes.			F
Bryant Division	Kalamazoo	Portage Creek	
Solids			B
Oxygen-demand wastes.			F s
King Division	Kalamazoo	Kalamazoo River	
Solids			A
Oxygen-demand wastes.			F s
Alma Products Co	Alma	Pine River via county drain.	A
Allen Packing Co	Charlotte	County farm drain.	A
American Box Board Co	Grand Rapids	Grand River	A
American Pulp & Paper Division.	Filer City	Ground water	A
		Mainstee Lake	B
		Lake Michigan	B p
American Brass Co	Detroit	Detroit River	A
Anderson-Bolling Co	Spring Lake	Ground water	A
Archer-Daniels-Midland Co.: Chemical Products Division.	Wyandotte	Detroit River	A
A. S. & P. Manufacturing Co.	Grand Haven	Grand River	A
Aurora Gasoline Co	Elsie	Maple River	B
	Muskegon Township, Muskegon County.	Little Black Creek.	F
Auto-Lite Battery Corp	Owosso	Shiawassee River	A
Automotive Materials Corp.: Pilgrim Drawn Steel Division.	Plymouth	Ground water	A
Bakelite Co.: Division of Union Carbide Corp.	Wyandotte	Detroit River	A
Baroda Manufacturing Co., Inc.	Baroda	Hickory Creek	A
Bay Refining Co	Bay City		
Oil waste		Saginaw River	B c
Phenol waste		Ground water	A
Belleville Plating Co	Belleville	Huron River	B
Belvidere Packing Co	Utica	Clinton River	G
Bendix Aviation Corp	Southfield	Rouge River	A
Blood Bros. Machine Co	Allegan	Kalamazoo River	A
Blissfield Canning Co	Blissfield	Ground waters	A
Bluebird Processing	Hart	Hart Lake	F
Bohn Aluminum Corp	Holland	Wildwood drain	B
Borden Milk Co	Mount Pleasant	Chippewa River	A
	Marlette	Connected to municipal system.	A
Briggs Manufacturing Co	Sterling Township, Macomb County.	Beaver Creek	A
Brochu & Hass Corp	Grand Rapids	Plaster Creek	B
Bronson Plating Co	Bronson	County drain 30 and Swan Creek.	A
Bronson Reel Co	do	Ground water	A
Brunswick-Balke-Collender Co.	Kalamazoo	Allen Creek	B
Buckeye Products Corp	Adrian	Raisin River	B
Budd Co	Detroit	Detroit River	A
Burroughs Corp	Plymouth	Rouge River	A
Cadillac Products, Inc	Sterling Township.	Ground waters	A
Calumet-Hecla, Inc	Calumet	Hill Creek and Lake Superior.	A
		Hamell Creek and Trap Rock River.	A
Campbell, Wyant & Cannon Foundry Co.	Roosevelt Park	Ruddiman drain	A
Candler Creamery Co	Kaleva	Big Beaver Creek	A
Capac Manufacturing Co	Capac	County drain	C
Carling Brewing Co	Frankenmuth	Cass River	E
Carnation Milk Co	Hesperia	White Riber	A
	Sheridan	Prairie Creek	A
Charmin Paper Products Co.	Cheboygan	Cheboygan River	B
Chelsea Spring Co	Chelsea	Letts Creek	A
Cherry Growers, Inc	Traverse City	Grand Traverse Bay.	A
Chrysler Corp., parts plant.	Centerline	Bear Creek via Centerline drain.	A
Chrysler Corp.:			
Defense Operations Division.	do	do	A
Michigan missile plant	Sterling Township, Macomb County.	Clinton River via Lockwood drain.	A
Cities Service Oil Co	Lowell	Grand River	A
Clark, W. N., Co	Caro	Ground waters	A
Clark Equipment Co	Buchanan	McCoy Creek	A
	Benton Township, Berrien County.	Ox Creek	A
	Jackson	Grand River	A
Cleveland-Cliffs Iron Co.:			
Ohio mine	Michigamme	Spur River	A
Humboldt mine	Humboldt	Lake Lory	A
Iron-ore beneficiation	Republic	Michigamme River.	A
Do	Negaunee Township, Marquette County.	Carp River	A
Cliffs-Dow Chemical Co	Marquette	Lake Superior	F
Cloverleaf Co-op Cheese Co.	Daggett	Phillips Creek	A
Consolidated Food Processors, Inc.	Ellsworth	Intermediate Lake.	F
Consolidated Paper Co.:			
North Side plant	Monroe	Raisin River	
Solids			B
Oxygen-demand wastes.			F
South Side plant	Monroe	Raisin River	
Solids			B
Oxygen-demand wastes.			F

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959—Continued

Industry	Location	Public waters affected	Industry rating
Consolidated Paper Co.—Continued			
West Side plant	Monroe	Raisin River	
Solids			A
Oxygen-demand wastes.			F
Constantine Board & Paper Co.	Constantine	Fawn River	A
Continental Motors Corp.	Muskegon	Muskegon Lake	A
Getty St. Plant	do	Ground water and Muskegon River.	B
Cross Co	Clinton Township.	Sweeney drain	A
Crystal Canning Co	Frankfort	Betsie Lake	A
Crystal Refining Co	Carson City	Fish Creek	B
Cycleweld Cement Products: Division of Crysler Corp.	Trenton	Detroit, River	A
Culligan Battle Creek Soft Water, Inc.	Battle Creek	Kalamazoo River	G
Daggett Cheese Co	Daggett	Hays Creek	A
Dana Corp	Ecorse	Detroit River	A
	Chelsea	Letts Creek	A
Darling, L. A., Co	Bronson	Ground water	C
Darling & Co	Grand Rapids	Indian Mill Creek	A
	Melvindale	Rouge River	A
De Kleine Packing Co	Bentheim	Little Black River	B
Delton Creamery	Delton	Crooked Lake	G
Denham Manufacturing Co.	Big Rapids	Muskegon River	B
D.T. & I.R. R yards	Flat Rock	Silver Creek	A
Detroit Edison Co.:			
Enrico Fermi Station sanitary sewage.	Monroe	Lake Erie	A
Diamond Crystal Salt Co.	St. Clair		
Sewage		Connected to municipal system.	A
Industrial wastes		St. Clair River	A
Douglas, H. A., Manufacturing Co.	Bronson	County drain 30	A
Dow Chemical Co	Midland	Tittabawassee River.	
Brine wastes			F s
Oxygen-demand wastes.			B
Taste- and odor-producing wastes.			B
Dow Chemical Co	Ludington	Lake Michigan	A
		Pere Marquette Lake.	A
Drummond Dolomite, Inc.	Detour	St. Marys River	A
Dunn Paper Co	Port Huron	St. Clair River	A
DuWel Decorative Co	Bangor	Black River	B
Dwan Canning Co	Shoreham	Ground water	A
		County drain	F
Eagle Ottawa Leather Co	Grand Haven	Grand River	G p
E. I. du Pont de Nemours & Co.	Montague	Lake Michigan	A
Electrochemicals Department.	Wyandotte	Detroit River	A
Grasselli Chemicals Department.	Ecorse	do	A
East Jordan Canning Co	East Jordan	Lake Charlevoix	A
Eaton Manufacturing Co.	Marshall	Kalamazoo River	A
Eau Claire Packing Co	Eau Claire	Farmers Creek	D c
Eddy Paper Co	White Pigeon	White Pigeon River.	A
Elberta Canning Co	Elberta	Betsie Lake	A
Electric Auto-Lite Co.:			
Bay Manufacturing Division.	Bay City	Saginaw River	A
Electro Metallurgical Co.:			
Division Union Carbide & Carbon Corp.	Sault Ste. Marie	St. Marys River	A
Elgin Milk Products Co	Galien	Galien River	A
Elk Rapids Canning Co	Elk Rapids	Elk Lake	B
Evans Products Co	Plymouth	Rouge River	A
Ewen Farmers Co-op Creamery.	Ewen	Ontonagon River	F
Faas Food Co	Central Lake	Intermediate Lake.	A
Fairmont Foods Co	Bad Axe	Bad Axe Creek	F p
F & M Packing Co. (Did not operate in 1958.)	Ludington	Pere Marquette River.	A
Do	Suttons Bay	Lake Michigan	A
Farmers Co-op Creamery	Freesport	Coldwater River	A
Federal Mogul Corp	Greenville	Flat River	A c
Federal Screw Products	Chelsea	Letts Creek	A
Federal Steel Co	Springfield Township, Oakland County.	Ground water	A
Fennville Fruit Exchange.	Fennville	Mann Creek via County drain.	A
Fermentation Products, Inc.	Newaygo	Muskegon River	A
Ferro Stamping & Manufacturing Co.	Mount Pleasant		
Industrial wastes		Chippewa River	A
Sanitary sewage		Connected to municipal system.	A
Firestone Tire & Rubber Co.:			
Firestone Steel Products Division.	Riverview	Detroit River	A
Fletcher Paper Co	Alpena	Thunder Bay River and Thunder Bay.	A
Food Industries of America.	Douglas	Kalamazoo River	A
Ford Motor Co	Brooklyn	Raisin River	A
	Monroe	do	A
	Ypsilanti	Huron River	A
Rouge plant	Dearborn	Rouge River	
Acid wastes			G s
Oil wastes			B
Cyanide wastes			A
Phenol wastes			B
Solids			A
Ford Motor Co	Sterling Township, Macomb County.	Clinton River via Lockwood drain.	B s
	Novi Township, Oakland County.	Norton drain	A
	Northville	Rouge River	A
	Bruce Township, Macomb County.	Fisher Creek	A
Ford Motor Co.:			
Lincoln-Mercury Division.	Wayne	Rouge River	A
French Paper Co	Niles	St. Joseph River	A
Frigid Foods, Inc	Sutton Bay	Grand Traverse Bay.	D
Frigo Bros	Carney	Porterfield Creek	B
Fuel Oil Corp	River Rouge	Detroit River	A
Garnsey-Dillon Co	Ida	Pitts drain and Plum Creek.	A
General Filters, Inc	Novi	Ground water	A
General Foods Corp.:			
Northland Dairy Division.	Evart	Muskegon River	A
General Motors Corp.:			
A C Spark Plug Division.	Flint	Flint River	A
Fisher Body plant No. 1	Grand Rapids	Plaster Creek via Cole drain.	A
Fisher Body plant No. 2	do	Ground water	B c
		Grand River	B
Buick Division	Flint	Flint River	A
Chevrolet-Saginaw gray-iron foundry.	Saginaw	Saginaw River	A
Chevrolet-Saginaw service manufacturing.	do	do	A
Diesel Engine Division	Wyoming Township, Kent County.	Plaster Creek via County drain.	B
Fisher Body Division	Grand Blanc	Thread Creek	A
Chevrolet-Flint Division.	Flint	Flint River	A
Detroit Diesel Engine Division.	Detroit	Rouge River	A
Do	Wayne	do	A
Detroit Transmission Division.	Willow Run	Willow Run	A
Oldsmobile Forge Division.	Lansing	Grand River	A
Chevrolet Division, engine plant.	Flint	Carman Creek	A
Chevrolet—Flint assembly.	do	Swartz Creek	A
Parts Division	do	do	A
Ternstedt Division	do	Hughs drain	A

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959—Continued

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959—Continued

Industry	Location	Public waters affected	Industry rating
General Motors Corp.—Continued			
Fisher Body & Chevrolet Division, engineering center.	Warren township, Macomb County.	Bear Creek	A
General Motors Technical Center.	do	do	A
General Shoe Co	Whitehall	White Lake	A
Gerber Products Co	Fremont	Ground water	A
		Darling Creek	B
Gibson Refrigerator Co	Greenville	Flat River	A
	Belding	do	A
Gielow, J. J. & Sons	Croswell	Black River	E
Goodrich, B. F., Co	Cadillac	Clam River	A
Gould Battery Co	Monroe	Plum Creek	G
Grand Haven Brass Co	Grand Haven	Grand River	C
Grand Trunk Railroad Co.: Car Shops	Battle Creek	Battle Creek River.	A
Great Lakes Chemical Co.	Filer City	Manistee Lake	G p
Great Lakes Steel Corp	Ecorse	Detroit River	
Oil wastes			A
Acid wastes			B
Great Lakes Steel Corp.:			
Blast Furnace Division.	River Rouge	Detroit River	A
Michigan Steel Division.	Ecorse	do	A
Hamilton Paper Co.:			
Michigan Division	Plainwell	Kalamazoo River	
Solids			B
Oxygen-demand wastes.			F s
Hanna, M. A., Ore Co.:	Iron River	Iron River	
Hiawatha mine			A
Homermine			A
Cannon mine			A
Harbeson-Walker Refactories, Inc.	Ludington	Pere Marquette Lake.	A
Hart Cherry Packers, Inc.	Hart	Hart Lake	F
Hart & Cooley Manufacturing Co.	Holland	Black River	A
Hartford Metal Protection Co.	Hartford	Cemetery drain and Pine Creek.	B
Hawthorne Paper Co	Kalamazoo	Kalamazoo River	
Solids			F
Oxygen-demand wastes.			C
Heinz, H. J., & Co	Holland	Lake Macatawa	A
Hercules Powder Co.:			
Huron Milling Division.	Harbor Beach	Lake Huron	B
Hess Duck Farm	Hemlock	McClellan Run drain.	A
Higbee Manufacturing Co.	Rochester	Paint Creek	A
Hilfinger Corp	Jackson	Grand River	B
Holland Color & Chemical Co.	Holland	Lake Macatawa	F p
Hooker Electro-Chemical Co.	Montague	White Lake	A
Home Canning Co	Blissfield	Raisin River	B
Hoover Ball & Bearing Co.	Pittsfield Township, Washtenaw County.	Wood outlet drain.	F p
Universal Die Casting Division.	Saline	Saline River	B p
Howes Leather Co., Inc	Boyne City	Lake Charlevoix	A
Hudson Plating Co	Hudson	Bean Creek via Garrison drain.	A
Hudsonville Creamery	Burnips	Rabbit River	A
Hudsonville Dairy	Hudsonville	Rush Creek	B
Hurd Lock and Manufacturing Co.	Adrian	Raisin River	A
	Almont	Connected to municipal system.	A
Huron Portland Cement Co.	Alpena	Thunder Bay	A
Huss Ontonagon Pulp & Paper Co.	Ontonagon	Ontonagon River	B
Industrial Rubber Goods Co.	St. Joseph	Abraham drain	A
Inland Lime & Stone Co.	Manistique	Lake Michigan	A
Inland Steel Co.:			
Sherwood Mine	Iron River	Iron River	A
Interurban Creamery	Jamestown	Buttermilk Creek	A
Jebovy Canning Co	Ludington	Pere Marquette Lake.	A
Jervis Corp	Grandville	Grand River	B
John C Morgan Co	Traverse City	Grand Traverse Bay.	A
Jordan Valley Co-op	East Jordan	Lake Charlevoix	A

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959—Continued

Industry	Location	Public waters affected	Industry rating
Kalamazoo Paper Co.:			
Mills 1 and 3	Kalamazoo	Kalamazoo River	
Solids			A
Oxygen-demand wastes.			F s c
Mill 2	Kalamazoo	Kalamazoo River	
Solids			A
Oxygen-demand wastes.			B s
Kalamazoo Rendering Co.	Comstock	Comstock Creek	A
Kalamazoo Vegetable Parchment Co.:			
Mill 1	Parchment	Kalamazoo River	
Solids			A
Oxygen-demand wastes.			C s
Mill 2	Parchment	Kalamazoo River	
Solids			A
Oxygen-demand wastes.			C s
Kawneer Co.:			
Plant No. 1	Niles	St. Josephs River	A
Plant No. 3	do	Brandywine Creek.	A
Keeler Brass Co	Middleville	Thornapple River	A
King Seeley Corp	Scio	Huron River	A
Kingsford Chemical Co	Kingsford	Ground waters	A
Kingsley Square, Inc	Bloomfield Hills	Rouge River via Barbour drain.	B
Kraft Foods Co., Inc	Pinconning	Pinconning River	A
Kroger Co	Paris Township, Kent County.	Plaster Creek	A
Leco Plating Co	St. Joseph	Ground water and Hickory Creek.	B
Lakeside Refining Co	Kalamazoo	Allen Creek	A
Lawrence Canning Co	Lawrence	Brush Creek	A
Lee Paper Co	Vicksburg	Gourdneck Creek	B s
Le Fere Forge & Machine Co.	Jackson	Grand River	A
Leonard Refineries, Inc	Alma		
Oil Wastes		Pine River	B
Phenol wastes		Ground waters	B
Leonard Refineries, Inc.:			
Midwest Division	Alma	Pine River	
Oil waste			A
Phenol waste			A
Roosevelt Oil Division.	Mount Pleasant	Chippewa River	
Oil wastes			A
Taste and odor producing wastes.			A
Light Metals Plating & Chemical Co.	Wayne	Rouge River	B
Linde Air Products	Montague	Ground waters	A
Lortin Products Co	East Saugatuck	Kalamazoo River	A
Litchfield Co-op Creamery Co.	Litchfield	St. Joseph River	A
Longworth Plating Co	Chelsea	Letts Creek	A
McKay Plating Co	Marysville	Ground water and St. Clair River.	B
McLouth Steel Corp	Trenton	Detroit River	B
	Gibraltar	Frank and Poet drain.	A
M & S Plating Co	Hudson	Bean Creek via Garrison drain.	A
Mac Sim Bar Paper Co	Otsego	Kalamazoo River	
Solids			A
Oxygen-demand wastes.			C s
Manistee Salt Co	Manistee	Manistee Lake	G
Manistique Pulp & Paper Co.	Manistique	Lake Michigan	F
Marathon Corp	Menominee	Menominee River	A
Marinette Paper Co.:			
Menominee Groundwood Mill.	do	do	B
Marvel Refining Co	Grand Rapids	Ground water	A
Marysville Plating Co	Marysville	St. Clair	B
Mead Corp.:			
Escanaba Division	Escanaba	Escanaba River	F
Mead-Johnson Co	Zeeland	Black Creek	A
Mergraf Oil Products, Inc	Northville	Rouge River	B
Michigan Carton Co.:			
Angell St. plant	Battle Creek	Kalamazoo River	F p
Fountain St. plant	do	do	F p
Michigan Chemical Corp	St. Louis	Pine River	
Solids			B
Toxic wastes			B
Acid			B
Brine			B
Michigan Chemical Corp.	East Lake	Manistee Lake	A

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959—Continued

Industry	Location	Public waters affected	Industry rating
Michigan Consolidated Gas Co.	Six Lakes	Flat River and First Lake.	A
Michigan Fruit Canners, Inc.	Fennville	Drain to Mann Creek.	A
Do	South Haven	Drain to Black River.	A
Michigan Milk Producers Association.	Imlay City	Belle River	A
	Peck	Elk River	A
	Ovid	Maple River	D
Michigan Mushroom Co.	Niles	St. Joseph River	A
Michigan Producers Dairy Co.	Sebewaing	Saginaw Bay	A
Michigan Seamless Tube Co.	South Lyon	Huron River	A
Michigan Sugar Co	Caro	Cass River	D
	Croswell	Black River	B
	Carrollton	Saginaw River	B
	Sebewaing	Saginaw Bay	D
Michigan Wineries, Inc	Paw Paw	Paw Paw River	F
Middleville Engineering Co.	Middleville	Ground water and Thornapple River.	B
Millburg Fruit Exchange	Millbug	Blue Creek	A
Misco Precision Casting Co.	Whitehall	White Lake	A
Monitor Sugar Co	Bay City	Squaconning Creek.	A
Monroe Auto Equipment	Monroe	Raisin River	B
Monroe Paper Products Co.	do	do	
Solids			A
Oxygen-demand wastes.			F
Monsanto Chemical Co	Trenton	Detroit River	A
Montcalm Creamery Co	Greenville	Flat River	A
Morton Salt Co	Marysville	St. Clair River	A
	Manistee	Manistee Lake	G p
Mount Clemens Metal Products.	Mancelona	Ground water	A
	Mount Clemens	Ground water and Clinton River.	C
Muller, E. B., & Co. (Operated by H. Franck Sons, Inc.).	Pinconning	Pinconning River	A
Muller, E. B., & Co	Pigeon	Pigeon River	A
Munising Paper Co	Munising	Lake Superior	
Pulp mill			B
Paper mill			B
Murray Packing Co	Plainwell	Kalamazoo River via intercounty drain.	D
Naph-Sol Refining Co	North Muskegon	Cedar River	B
Nash-Kelvinator Corp	Grand Rapids	Plaster Creek	A
National Carbide Corp	Wyandotte	Detroit River	A
National Gypsum Co	Kalamazoo	Kalamazoo River	
Solids			A
Oxygen-demand wastes.			C s
National Machine Products.	Utica	Clinton River	A
National Twist Drill Co	Rochester	Stoney Creek	A
Nestles Company, Inc	Ubly	Cass River	A
New Era Canning Co	New Era	Carlton Creek	B
New York Airbrake Co	Galesburg	Kalamazoo River	A
New York Central R.R	Bay City	Kawkawlin River	A
	Jackson	Grand River	A
North American Extrusion Corp.	Parchment	Travis Creek	B
North Range Mining Co.:			
Book mine	Alpha	Mastodon Creek and Buck Lake.	A
Northport Cherry Factory, Inc.	Northport	Grand Traverse Bay.	B
Novi Equipment Co	Novi	Rouge River	A
O & S Bearing Co	Whitmore Lake	Huron River via county drain.	A
Ogemaw Packing Co	West Branch	C. K. Eddy Creek.	A
Oliver Iron Mining Corp	Ironwood	Powdermill Creek.	A
Ontonagon Valley Co-op Creamery.	Bruces Crossing	Clear Creek	B
Ott Chemical Co	Dalton Township, Muskegon County.	Ground water	B
Osceola Refining Co	Reed City	Hersey Creek	A
Otsego Falls Paper Mills, Inc.	Otsego	Kalamazoo River	
Pulp mill			A

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959—Continued

Industry	Location	Public waters affected	Industry rating
Otsego Falls Paper Mills, Inc.—Continued			
Paper mill:			
Solids			B p
Oxygen-demand wastes.			C s
Otsego Sanitary Milk Co.	Otsego	Connected to city system.	A
Falestine Cheese Co	Stephenson	Big Brook	A
Parke-Davis Co	Holland	Ground water and Lake Macatawa.	A
Paw Paw Canning Co	Paw Paw	Paw Paw River	F
Peerless Cement Co	Detroit	Rouge River	A
Peet, G. M., Packing Co	Chesaning	Shiawassee River	B
	Grand Rapids	Indian Mill Creek	A
Pelkie Cheese Co	Pelkie	Sturgeon River	A
Peninsular Paper Co	Ypsilanti	Huron River	B
Pennsalt Chemicals Corp:			
Industrial Division	Wyandotte	Detroit River	A
Organic Chemicals Division.	Riverview	Monguagon Creek.	B p
Pet Milk Co	Coopersville	Deer Creek	A
	Wayland	Rabbit River	A
Petoskey Portland Cement Co.	Petoskey	Little Traverse Bay.	A
Petoskey Plating Co	do	Bear Creek	A
Petroleum Specialties, Inc.	Flat Rock	Silver Creek	B
Pickands Mather & Co.:			
Bershire mine	Caspian	Bakers Creek	A
Fortune Lake mine	Crystal Falls	Briar Hill Creek	A
Pickford Creamery Co., Inc.	Pickford	Munuscong River	A
Pittsburgh Forging Co	Jackson	Grand River	A
Plainwell Canning Co	Plainwell	Kalamazoo River	A
Port Huron Sulphite & Paper Co.	Port Huron	Black River	B
Quincy Products Co	Quincy	Marble Lake via county drain.	B
Rapid River Cooperative Creamery.	Rapid River	Rapid River	F
Ray Weeks Packing Co	Richmond	Belle River via road ditch.	B
Redi-Foods, Inc	Davison Township, Genesee County.	Ground waters	A
Remus Creamery Co	Remus	Pine Lake drain	F
Reynolds Chemical Products:			
Division of Strubnitz-Green Corp.	Whitmore Lake	Horse Shoe Lake outlet drain.	B
Revere Copper & Brass, Inc.	Detroit	Detroit River	A
Rex Paper Co	Kalamazoo	Kalamazoo River	
Solids			B
Oxygen-demand wastes.			F s
Riley Creamery Co	Marlette	Connected to Municipal system.	A
River Raisin Paper Co	Monroe	Raisin River	
Solids			A
Oxygen-demand wastes.			F
Riverside Packing Co	Jackson	Grand River	A
Rochester Paper Co	Rochester	Clinton River	A
Rockford Paper Mills, Inc.	Childsdale	Rouge River	F c
Rockwood & Co	Amble	Tamarack Creek via county drain.	D
Rocky River Paper Mills, Inc.	Three Rivers	St. Joseph River	A
Rudy Manufacturing Co.	Dowagiac	Dowagiac Creek	F
Rudyard Creamery Co	Rudyard	Pine River	A
St. Julian Wine Co., Inc	Paw Paw	Paw Paw River	F
Saranac Manufacturing Co.	Saranac	Ground water	A
Saranac Milk Co	do	Lake Creek	G s
Samary Food Products	Coopersville	Deer Creek	B
Schafer Manufacturing Co.	Union City	St. Joseph River	B
Schmidt Packing Co	Niles	Dowagiac Creek	A
Sealed Power Corp	Muskegon Heights.	Ruddiman drain	B
Sebewaing Brewing Co	Sebewaing	Sebewaing River	A
Scott Paper Co	Detroit	Rouge River	C
Shawinigan Resins Corp.	Trenton	Detroit River	B
Simplex Paper Corp	Palmyra	Raisin River	A
Simplicity Pattern Co., Inc.	Niles	St. Joseph River via Creek.	B

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959—Continued

Industry	Location	Public waters affected	Industry rating
Socony-Mobile Oil Co.	Trentor	Detroit River	
Oil			F c
Phenol			F c
South Haven Chemical Co.	South Haven	Black River	A
Sodus Fruit Exchange	Sodus	Pipestone Creek via county drain.	F p
Standard Lime & Cement Co.	Manistee	Manistee Lake	G p
Standard Tube Co.	Redford Township, Wayne County.	Livonia drain	A
Stokely Foods, Inc.	Scottville	Pere Marquette River.	B
	Croswell	Black River	A
	Hart	Hart Lake	F
Stover Soft Water Service	Berrien Springs	St. Joseph	B
Strelinger, Chas. A., Co.	Warren	Red Run	A
Sumner Chemical Co.	Zeeland	Hunter Creek	F sc
Sundquist Creamery Co.	Henderson	North Side county drain.	B
Supreme Polishing & Buffing Co.	Centerline	Bear Creek	B
Sutherland Paper Co.:			
Division 1	Kalamazoo	Kalamazoo River.	
Solids			A
Oxygen-demand wastes.			C s
Divisions 4 and 7	Kalamazoo	Kalamazoo River.	
Solids			A
Oxygen-demand wastes.			C s
Sylvania Electric Products:			
Argus Camera Division.	Ann Arbor	Huron River	A
Tecumseh Products Co.	Tecumseh	Raisin River	C
Telfer Packing Co.	Owosso	Shiawassee River.	A
Thompson Products, Inc.	Warren	Beaver Creek	B
Traverse City Canning Co.	Traverse City	Boardman River	B
Trilex Corp.	Canton Township, Wayne County.	Rouge River	A
Tri-State Cooperative Association.	Montg nery	St. Joseph River (Maumee Basin).	A
Turner Cheese Co.	Turner	County drain	A
U.S. Gypsum Co.	River Rouge	Rouge River	A
U.S. Rubber Co.	Detroit	Detroit River	A
Utica-Bend Corp.	Utica	Clinton River	
Sewage			A
Industrial wastes			B
Utilex Corp.	Fowlerville	Red Cedar River	A
Upjohn Co.	Kalamazoo	Portage Creek and ground water.	A
Valley Chemical Co.	Mount Pleasant	Chippewa River	C
Vogt Packing Co.	Grand Blanc	Thread Creek	A
Warren Featherbone Co.	Three Oaks	Deer Creek	A
Warren, S. D., Co.	Muskegon	Muskegon Lake	D c
Watervliet Paper Co.	Watervliet	Paw Paw River	B
Welch Grape Juice Co.	Lawton	Lawton Creek	F
West Branch Refineries, Inc.	West Branch	C. K. Eddy Creek.	A
West Michigan Fruit Growers, Inc.	Hart	Hart Lake	F
White Pine Copper Co.	White Pine	Mineral River	A
White Products Corp.	Middleville	Ground waters	A
Whitehouse Milk Co.	Stephenson	Little Cedar River.	A
Wolverine Finishes Corp.	Wyoming Township, Kent County.	Plaster Creek	F
Wolverine Shoe & Tanning Co.	Rockford	Rogue River	A
Wolverine Fabricating & Manufacturing Co.	Dundee	Raisin River	A
Wyandotte Chemicals Corp.:			
North works	Wyandotte	Detroit River	A
South works	do	do	A
Yale Woolen Mills	Yale	Mill Creek	G
Young, L. A., Spring & Wire.	Canton Township, Wayne County.	Rouge River	B
Youngstown Mines Corp.	Ironwood	Powdermill Creek.	A
Zeeland Processing Co.	Zeeland	Branch of Black River.	A

Michigan Water Resources Commission—Industrial pollution status, Apr. 1, 1959—Continued

SUMMARY

	Apr. 1, 1958	Apr. 1, 1959
Number of plants	390	400
Number of problems	439	449
Number of problems:		
Class A	265	278
Class B	85	92
Class C	16	15
Class D	8	8
Class E	2	2
Class F	48	42
Class G	15	12
Total	439	449

NOTE.—Refinery oil wastes rated by department of conservation, oilfield-hazard reduction.

EXHIBIT NO. 14

PROGRESS TOWARD WATER RIGHTS LEGISLATION IN MICHIGAN

(By Norman Billings)

Specific accomplishments in the field of water rights in recent years may be lacking or at least obscure. Nevertheless, we believe that real progress has been made in broadening and strengthening the base of understanding that is so indispensable to the eventual solution of Michigan's water rights problems.

Worthy of special note along this line is the graduate course in water rights conducted last winter and spring terms by Dr. Humphrys, of the Resource Management Department at Michigan State University. This course, which brought together detailed information on the nationwide water rights situation, was attended by some 75 students of resource management from widespread locations, many of whom occupy key positions in public agencies and private organizations. Marking the first extended attention to water rights problems by organized groups in Michigan, the water rights course provided a forum for coordinated analysis and debate of the problem's many complexities. Many of the students submitted articles on the subject to local newspapers, which undoubtedly contributed materially to improved public understanding.

This year saw also the beginning of organized legal studies of water rights. Under the direction of William J. Pierce, professor of law, intensive research was conducted by a group of graduate students at the legislative research center on behalf of the National Conference of Commissioners on Uniform State Laws. Tentative drafts of a model water use law were developed on the basis of that research and several meetings have been held among representatives of various interests to review the drafts and suggest revisions. The most recent of these meetings was a 3-day session on "Water Resources and the Law" held at Ann Arbor September 4–6.

In the State legislature, a senate resolution to continue the joint interim committee on water resources was not reported out of the house committee on rules and resolutions. The house approved appointment of its own interim committee, but the senate is left without representation this year.

At a recent meeting of the water resources commission, Mr. Adams, executive secretary, recommended preparation by staff of bills to authorize use of diffused surface water, floodwaters, and water from the Great Lakes and lower reaches of tributary rivers for irrigation, and to restrict such use from inland lakes and streams during periods of water scarcity and conflict among uses. These bills would not be expected to answer in full the need for water rights legislation. They would be aimed toward validating agricultural uses that are clearly compatible with good husbandry of the resource and toward protection of gains in pollution control that are now threatened by further unregulated depletion of droughttime streamflow. Because of its representation of all water interests, and its statutory duties, it would appear eminently appropriate for the commission to seek the timely enactment of legislation along these lines.

In other States, much activity is noted. Many States have continued studies, and in Florida a special study commission submitted a report calling for statutory water rights law. In Iowa, a comprehensive water rights law was unanimously passed by the legislature, signed by the Governor, and given immediate effect. Mississippi enacted water rights legislation last year that will go into effect in 1958. The new laws of these two States may be suitable to conditions there. We do not believe they would work in Michigan. In Wisconsin, the natural resources committee of State agencies completed and published a 159-page report on the natural resources of the State. It did not specifically recommend water rights legislation, but that matter became the subject of some controversy last spring when bills proposed by some interests were opposed by others.

A substantial addition was made this year to information on irrigation water use in Michigan. Forty-five counties, including those where irrigation is practiced most extensively, have been carefully surveyed. Copies of the summary of findings are available at the water resources commission offices. Surveys of the remaining counties will be completed within the next few months.

Modest expansions have been made in the stream-gaging program but, it is still far short of what will be required to effectively administer any water rights legislation. A senate bill to license water-well drillers and require the filing of water-well logs failed to pass.

A most useful tabulation of low flow characteristics of Michigan streams was completed last November under a cooperative program with Dr. Clarence Velz, of the School of Public Health, University of Michigan. Detailed analysis of those characteristics is being made under a continuation of the program.

The slowness with which statutory water law approaches reality is probably due largely to the fact that, so far, it has been possible to get along without it. Over and beyond that, however, is the unpleasant fact that there is by no means a clear path toward satisfactory solution of water rights problems no matter what law is enacted. It is our belief that the water rights issue is brought on mostly by the use of water for irrigation. Certainly, there are many other fields of water-use conflict, but it seems to us that most, if not all, of these can be resolved with relatively simple new or amendatory law. Statutes governing diversions for consumptive use, on the contrary, impress us as calling either for rather exhaustive and detailed coverage of the many complexities that are involved or the investment of an administrative agency with a great deal of discretionary power. In any case, the administrative duties that would be imposed by a law which will protect established values and yet permit the fullest possible development of new values would appear to be very heavy. No two streams are the same in their capacities to sustain consumptive uses, and very few streams are dependably the same from one season to the next. Arbitrary and general rules cannot be expected to suffice in providing for their fullest use. Instead, each permissive clause and each restrictive clause would seem to call for provisos to cope with the many special conditions that will unavoidably arise.

For much of the State's potential irrigation area, the cold, statistical records of streamflow offer little basis for hoping that direct summertime diversions from lakes and streams can be increased very much. On the other hand, those same records, collected through the years by the U.S. Geological Survey, show that extremely large quantities of water escape each winter and spring without serving very much, if any, use. This situation patently suggests that water rights law must be largely restrictive with regard to summer diversions, and permissive with regard to the storage of seasonal excess water. Active interest in the latter has not yet been apparent, and it may be that its potentialities will not attract much attention until the inevitable curtailment of further summertime diversions is imposed. Deferring that curtailment is hardly a service to the irrigator, for it can only lead to his increasing harassment by competitive users, either through lawsuit or through interception of his supply.

(Presented at the annual meeting of Michigan Natural Resources Council, Oct. 15, 1957.)

WATER USE FOR IRRIGATION—A SURVEY OF WATER USE IN AGRICULTURAL AND MUNICIPAL IRRIGATION

(By the Michigan Water Resources Commission Hydrology Division, Lansing, Mich. 1959)

FOREWORD

This report presents the findings of a statewide irrigation survey that was completed in late 1958 by the water resources commission. Included is an analysis of growth trends and predictions. Part of the report is devoted to descriptions of specific regions of the State where irrigation is a particularly important agricultural activity. Other information in connection with both agricultural and municipal irrigation is presented.

Previously completed studies concerning the economics and engineering of irrigation have been published by the Departments of Agricultural Economics and of Agricultural Engineering, Michigan State University. These may be of interest to the reader and are available on request from the above-named departments.

No information is presented on the use of water for residential lawns or gardens. It is recognized that many thousands of acres are represented in this form of supplemental irrigation. However, these water supplies come mainly from municipal sources and are considered as part of municipal water needs.

The preparation of this report has been immeasurably expedited by the cooperation of the many irrigators, equipment dealers, and agencies contacted during the course of the survey. Special recognition is extended to personnel of the U.S. Soil Conservation Service, Michigan State University, and the Agricultural Extension Service.

INTRODUCTION

To those who associate irrigation activities with the huge reservoirs and vast watered tracts of western desert wastelands, it may come as a surprise to learn that Michigan farmers have been engaged in this practice since before 1930. Just how extensive this "new" farming technique was utilized before that date is not fully known; however, information obtained in this survey indicates that there were 214 systems operating prior to 1930.

The water resources commission has, as one of its statutory duties, the responsibility "to make or cause to be made surveys, studies, and investigations of the uses of the waters of the State." This authority to study and evaluate the uses of this resource establishes the basic need to review irrigation activities in Michigan.

In 1951, this agency, in cooperation with the Agricultural Extension Service, Michigan State University, initiated a letter survey with the county agricultural agents throughout the State. County maps were supplied each agent for indicating the general location of each known irrigator, the number of acres irrigated, and the source of water supply. This initial review indicated that 390 farmers were irrigating about 14,000 acres of crops that year. Although the letter returns from this survey were not complete for the State, the available data clearly indicated the need for a more detailed and comprehensive evaluation of this expanding use of the State's water resources.

The detailed field inventory was started in the summer of 1954 and was conducted on a part-time basis until the fall of 1956, at which time Mr. Jon-Eric T. Stenson, water conservationist, was assigned on a full-time basis. The survey was completed in April 1958 and, since that time, Mr. Stenson, as time permitted, has prepared this report. Assistance has been given by other members of the hydrology division in the analysis and evaluation of the data.

The major objective of the field survey was to determine the extent and significance of the irrigation water usage. To attain that objective, complete information was sought on the size and location of irrigated tracts, crops irrigated, water-application rates, source of water supply, and related data. The entire State was inventoried, county by county. In most cases the list of irrigators developed from the 1951 survey was augmented by new data from county agents, local soil conservationists, irrigation equipment suppliers, and others before the actual canvass was started in a county. Irrigators contacted also assisted by supplying the names of other operators in their neighborhood. With few exceptions, every irrigator in a county was interviewed. Usually the county agricultural agent was able to supply basic information on the few operators who could not be contacted. Careful attention was also paid to irrigation projects involving golf courses, parks, cemeteries, large-scale lawn systems, and other miscellaneous nonagricultural users.

FINDINGS

Irrigation in Michigan

Irrigation, either agricultural or municipal, or both, is being practiced in every county in the State with the exception of Alger and Gladwin Counties. The amount of irrigated land per county varies from a low of 3 acres to a high of almost 10,000 acres. The county average is about 30 systems irrigating 825 acres. The average system irrigates about 28 acres.

The amount of agricultural land irrigated, expressed as a percentage of total cropland harvested and cropland pastured,[1] is about 0.6 percent. In several counties more than 1 percent of the agricultural land is irrigated, and Berrien County, with the greatest amount, has about 5 percent. The tremendous irrigation potential in Michigan from the standpoint of available agricultural land is evident from the above figures.

Crops comprising the greatest irrigated acreage are strawberries, tree fruits, potatoes, truck crops, and municipal[2] (cemeteries, parks, and golf courses). As of April 1958, there was a total of 68,481 acres irrigated by 2,476 systems. Surface waters supply the greatest acreage (55 percent), with ground water (29 percent) and city water (9 percent) second and third, respectively. Combined sources are also used.

The water application rates vary with rainfall, topography, soil conditions, amount of water available, labor and capital available, and type of crop irrigated, This survey indicates that, during a season of average precipitation, irrigators normally apply about 4.3 inches per acre.

Application rates on flowers and nurseries exceeded all others, averaging about 6 inches per year. The rates on raspberries and field crops were the least with an average of 3½ inches.

Irrigation today is of considerable importance to the State's agricultural economy. Irrigation can and does double, and sometimes triple, crop production as well as improve quality and is, therefore, a factor of major importance to farm operations and economy. Many farmers report that it is profitable under some circumstances to irrigate such crops as pasture and hay as well as other relatively low-value crops.

The Upper Peninsula

At present, irrigation in the Upper Peninsula is not widely practiced, with only 1,634 acres reported in this survey. Farmers in some areas are finding supplemental irrigation profitable. The main developments to date are centered in the Houghton County strawberry-potato area and other potato growing regions scattered throughout the peninsula.

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[1] From USDA census.

[2] For purposes of report brevity, these uses are hereafter included under the category of "Crops."

Summary of irrigation—83 counties, Michigan

Prepared from information collected by water resources commission staff in field interviews with irrigators. Field survey completed in April 1958]

HISTORY OF IRRIGATION

Year	Number of systems installed	Year	Number of systems installed
Prior to 1930	214	1947	98
1930	39	1948	116
1931	10	1949	111
1932	17	1950	166
1933	7	1951	118
1934	13	1952	138
1935	37	1953	159
1936	16	1954	189
1937	21	1955	215
1938	10	1956	[1] 235
1939	10	1957	[1] 84
1940	32	1958	[1] 6
1941	12	Unknown	194
1942	20		
1943	7	Total number of systems in State	2, 476
1944	18		
1945	62		
1946	102		

[1] This does not indicate a decrease in rate of growth. Field survey was being completed during this time.

MAJOR CROPS IRRIGATED

	Acres
Flowers and nurseries	4, 794. 25
Strawberries	6, 796. 00
Raspberries	1, 413. 75
Blueberries	1, 732. 00
Tree fruits	5, 490. 75
Other small fruits	30. 00
Potatoes	8, 853. 50
Tomatoes	2, 144. 00
Truck crops	11, 598. 50
Field crops	4, 098. 50
Melons, pickles, and cucumbers	3, 790. 50
Hay, pasture, and silage	2, 151. 00
Cemeteries, parks, and golf courses	13, 336. 25
Miscellaneous	2, 252. 25

IRRIGATION WATER SUPPLY DATA

Source	Number of systems	Acres irrigated	Portion of irrigated land
			Percent
Ground water	829	20, 014. 25	29. 23
Surface water	1, 380	37, 396. 50	54. 61
City	163	6, 474. 50	9. 45
Combined	104	4, 596. 00	6. 71
Total	2, 476	68, 481. 25	100. 00

Most irrigators in Houghton County started after World War II. Five hundred and sixty-six acres, mainly agricultural, are irrigated at present. Potatoes and strawberries are of primary importance in the region and many farms are equipped with irrigation systems for frost protection and moisture control.

Rainfall in Houghton County is usually adequate to provide good yields of potatoes. Occasional shortages, however, make supplemental irrigation desirable, and near-record yields of irrigated potatoes are common in this area. Several potato growers are irrigating large acreages in the county at the present time. Agricultural leaders anticipate that more potato growers will adopt the practice in the near future.

Strawberry production in the county has been an important source of income for some time. Varieties grown are late maturing and of good quality. Market outlets are located in Wisconsin, Minnesota, Illinois, and upper Michigan. Houghton County's crop reaches the market several weeks following lower Michigan's fruitbelt berry production and has lengthened the fresh berry season. Irrigators not only have improved the quality and quantity of this cash crop but also have available the means of adequate frost protection so essential to strawberry production, particularly in this northern area.

Other regions of the Upper Peninsula where irrigation is used include Luce, Dickinson, and Iron Counties. Potatoes are the most commonly irrigated crop and sometimes a period of 2 or 3 years may go by without the need for supplemental moisture.

Surface water supplies are readily available in most farm areas of this peninsula and are more frequently utilized than ground waters, which are relatively limited in many regions. It is doubtful whether many serious disputes will arise soon over water rights. However, there have been some minor cases in recent years. Consequently, most of the irrigators are interested in possible water rights legislation and how it will affect their farming operations.

Southwest Michigan

The fruitgrowing area of southwestern Michigan is the most intensively irrigated part of the State and, even though rainfall is the heaviest in this region, the value of supplemental irrigation to the agricultural economy is of considerable importance. Thousands of acres of small fruit, vegetables, and tree fruit are irrigated annually both for frost and drought protection.

Farmers in this region were probably the first in the State to realize the values of irrigation, not only from the standpoint of increased yields but also for the production of higher quality crops. The practice has become so important that availability of water is becoming a factor to consider when purchasing agriculture land.

Several disputes over water rights have occurred in this region and the agricultural aspects of water rights legislation is of widespread interest to the farm irrigator.

Irrigation in this part of Michigan started gaining importance in the late thirties and the acreage irrigated has increased substantially each year. Three or four irrigated farms per square mile are not uncommon in parts of Van Buren and Berrien Counties. Chief emphasis is placed on small fruit and tree fruit production, which amounts to over 50 percent of the total irrigated acreage.

Surface water is the main source of supply, with an apparent gradual shift to ground water developing because of its relative freedom from legal problems.

Irrigated land in southwestern Michigan will undoubtedly continue to increase in acreage. The high-value crops and the healthy economic confliction of agriculture make irrigation expansion practical and desirable so long as water is available.

The industrial southeast[3]

Irrigation in this area is very important to agriculture. The high value of farmland, in addition to keen market competition, forces the farmer to raise high-value, high-quality crops.

Agricultural irrigation is primarily for drought prevention. However, frost-control irrigation on strawberries is practical and is applied on a limited basis. Water used is the heaviest on truck crops, with application rates being least on potatoes. Irrigated farms are scattered throughout the region, which is served by an excellent road network into marketing areas. Ground, surface, and municipal waters are all used extensively in this area. However, the limited availability of suitable surface water and the relatively high cost of municipal water have forced some farmers to utilize ground-water resources where available. Growth and increase of irrigation intensity in this area seems unlikely to continue much longer. High property values created by industrial and municipal expansion into the agricultural areas, with resulting higher taxation, bring about an unfavorable economic climate for agriculture.

Farm irrigators already are faced with competition for surface water by municipal irrigation needs involving thousands of acres, by industry, and by recreational interests. Farmland is rapidly being converted to subdivisions for homes and into complex industrial parks. According to the U.S. Department of Agriculture census, this area has lost about 25 percent of its cropland to other land uses in the past 10 years. The resulting high value of the remaining cropland, coupled with the market demands for fresh, high-quality produce, has forced irrigation of increasingly greater percentages of the declining truck crop acreage.

The west-central potato region

Montcalm County and parts of other adjacent counties comprise the State's foremost irrigated potato-growing region. Irrigation there developed rapidly in the years immediately following World War II. With additional application of fertilizer, it has in many cases resulted in acre yields of about double those of nonirrigated tracts. Irrigation is common throughout this region and continued increase in the practice is expected in the future. Montcalm County, with only 968 acres irrigated in 1947, had 2,866 acres irrigated in 1956—an average growth of about 200 acres per year.

Potato production is of major importance, although other crops are irrigated also. Surface- and ground-water sources, with considerable emphasis on storage ponds, supply water for these needs. Water rights conflicts between agriculture and recreation, although minor, have arisen on occasion. There is a tendency here, as well as in other parts of the State, for irrigators of large tracts to rely on ground water more than on other sources.

Methods and practices

By far the most important use of irrigation, especially in southern Michigan, is for supplementation of natural supply during periods of rainfall deficiency. There has been a gradual shift, however, in certain areas, to a new irrigation concept which treats natural rainfall as a supplement to irrigation. Those operating under the new concept appear to be more successful, and they claim that by following a regular schedule of irrigation, geared to natural factors of weather, soil, topography, and crops, improved quality and quantity production is attained.

Application rates vary during years of normal precipitation. However, an average seasonal total of about 4.3 inches is indicated in the results of this survey. Certain crops require more water than others. Flowers and nurseries require the most, with an average application of about 6 inches per year. A serious problem in connection with drought irrigation results from the need being greatest when the least amount of surface water is available. Many irrigators are solving this problem by constructing ponds and reservoirs to store seasonal excess water or are drilling large-capacity wells. Application rates on major Michigan crops are shown in table 7 of this report.

Irrigation for frost-damage prevention, especially on small fruit, was being practiced on about 7,000 acres at the time of the survey. Although only about 1 inch of water is applied during the frost season, this amount is ordinarily sufficient to prevent major frost damage and thereby to greatly increase yields. This type of irrigation does not present many problems in connection with water supply, since it occurs at a time of the year when surface water normally is available in relative abundance. Demands for water for frost protection will continue to rise as the science is developed.

Other uses of irrigation are for wind erosion and fire control on muck soils and for various seeding and fertilizing operations.

Portable sprinkler equipment is used on most irrigated farmland in Michigan. Some of the older and smaller projects still employ fixed, overhead sprinkler systems, but they are gradually being replaced by modern equipment. Muck farms are, in some instances, subirrigated (by controlling the level of subsurface waters), as are certain general farms in Bay County and other flat areas. This type of irrigation is not as flexible as sprinkler methods and greater risk is involved because of the danger of soil saturation in the event of a sudden rainstorm. Furrow irrigation is little used because Michigan topography is not generally suitable for this method.

Growth of irrigation

Municipal and agricultural irrigation has been practiced in Michigan for more than 30 years, with 214 systems irrigating some 8,988 acres before 1930. The majority of irrigation at that time was municipal rather than agricultural. Agricultural irrigation became more prominent in the years just before and after World War II and a high rate of growth has continued up to the present time. Michigan had 2,476 systems irrigating 68,481 acres as of 1958.

Agricultural irrigation is increasing at a much faster rate than is municipal irrigation. In 1940 there were 314 agricultural irrigation systems (including nurseries) in the State as compared to 305 municipal systems. However, in 1957 (the last year for which full data are available) there were 2,087 farms and nurseries irrigated, as compared to 383 municipal irrigation systems (table 13).

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[3] Consisting of Wayne, Washtenaw, Oakland and Macomb Counties.

A trend toward using ground water and storage ponds as a source of supply is evident from information obtained in the survey. This trend is probably caused by the growing apprehension of irrigators that legal problems may result when surface waters are used. Many irrigators fear that legislation may be enacted that would prohibit or restrict their use of surface water during low-flow periods. Storage ponds and wells may present the most economical and safe solution under such conditions.

The average number of acres irrigated per system has been remarkably consistent over the years (table 16). The smallest number of acres per system occurred in 1939, when 27.57 acres per system was the average. The largest average, 30.05 acres per system, occurred prior to 1930. The 1957-58 acreage was 27.60 acres per system.

Certain crops showed a greater increase in irrigated acres than others, and growth trends in crop acreages are evident. Acreage showing the least growth includes municipal uses (parks, cemeteries, golf courses), flowers and nurseries and truck crops. In 1930, these uses included about 11,451 acres out of a total of 12,970, whereas in 1958 they comprised 29,729 acres out of a total of 68,481. Potatoes, strawberries, tree fruits, and certain other crops showed a pronounced increase in irrigated acres from 1930 to 1958 (table 11).

The overall growth of irrigation systems and acres does not appear to have been dependent on any one factor; however, two stand out as being especially significant. They are the availability of lightweight, portable irrigation equipment and the economic necessity of producing increased yields of high-quality crops. There appears to be no correlation between rainfall departure from normal and overall irrigation growth and, likewise, no specific evidence is present to link irrigation growth with fluctuations in overall farm economy (based on prices-paid, prices-received indexes). Therefore, competition and availability of modern equipment appear to be the major factors affecting and contributing to irrigation growth. Graphs illustrating irrigation growth and rainfall data are presented in this report.

PREDICTIONS

It is impossible to predict with accuracy future irrigation growth trends. However, a few factors affecting this growth are evident and included are the following:

Agricultural economics.—Agricultural conditions in many parts of Michigan make irrigation economically feasible. Increased production, along with higher quality produce, will encourage, and sometimes force, farmers to irrigate if they are to compete successfully with irrigators in their region.

Improved equipment.—The continuing development of new and better irrigation equipment at more economical cost is, and will be, a contributing factor to increased irrigation use in Michigan.

Water supply.—Wells and storage ponds will probably be increasingly favored as sources of supply in the future. Many irrigators anticipate restrictive water rights legislation and are interested in developing sources of supply that are less susceptible to use restrictions.

Present irrigation potential.—Few irrigators are utilizing their systems to full capacity. Many systems are designed to enable the farmers to irrigate their entire farms, if necessary, providing there are adequate sources of water. The 68,481 acres tabulated in the survey is the acreage irrigated during a year of average rainfall. A dry year could necessitate the irrigation of perhaps another 40,000 to 50,000 acres. Many farmers indicate that they would irrigate every crop on the farm if the need arose, whereas only the highest value crops and those most responsive to supplemental watering are normally irrigated. Therefore, it is possible, even with no increase in the number of systems, that much more land could be irrigated.

Competition for water may become the most important limiting factor in irrigation growth. Increased municipal and industrial demands, in addition to recreational uses, will result in increased resistance to agricultural consumption of water by direct diversion from lakes and streams during water-shortage periods. It is possible, however, that, even with limitations, twice as much or more land could be irrigated. According to growth trends indicated by survey findings, 80,000 acres or more will probably be under irrigation by 1961.

WATER SOURCE CLASSIFICATION

To improve the basis for evaluating the possible effects of irrigation upon water resources, the water source classification employed in the May 1958 release of tabulated data from this survey has been slightly revised. As reported herein, the following classification applies:

Surface water includes those sources from which withdrawals of water can be expected to produce early and rather complete effect in reduced streamflow, stream-channel storage, or lake levels, as follows:

1. Lakes.
2. Rivers and creeks.
3. Drains.

Also included in this classification are storage ponds whose supply is obtained from overland runoff, much of which would otherwise have reached streams or lakes.

Ground water includes those sources from which withdrawals of water are largely at the expense of ground-water storage, the effects of which upon streamflow, stream-channel storage, or lake levels would be relatively slight and under most circumstances inconsequential, as follows:

1. Wells.
2. Spring-fed ponds, sumps, and pits.
3. Swamps and marshes.

Also included in this classification are ponds whose supply is obtained in part from springs and in part from overland runoff.

City water includes any piped, municipal supply.

Combined water includes any combination of city water and ground water, city water and surface water, surface water and ground water.

PROPOSED AND ABANDONED SYSTEMS

During the course of the field survey, information on several proposed and abandoned systems was obtained. The reported data do not indicate the total number of such systems. No effort was made to interview all such proposed or abandoned irrigation projects, and information on those systems that were tabulated was incidental to the basic purpose of obtaining information on existing and regularly used systems.

In addition to proposed and abandoned systems, certain existing and regularly used systems are omitted from the tabulation because it was not possible, for various reasons, to complete the field data forms. A summary of these known proposed, abandoned, and incompletely reported systems is as follows:

	Number of systems	Acres irrigated
Proposed	28	200 plus.
Abandoned	39	136 plus.
Incomplete	12	125 plus.

IRRIGATED CROP CLASSIFICATION

Flowers and nurseries (farm, forest, and commercial):
  1. All flowers.
  2. All nurseries.
  3. All bulbs.
  4. Other nursery products.
Strawberries.
Raspberries.
Blueberries.
Tree fruits.
  1. Apples.
  2. Pears.
  3. Peaches.
  4. Cherries.
  5. Plums.
Other small fruits:
  1. Grapes.
  2. Currants.
  3. Gooseberries.
  4. Cranberries.
  5. Other small fruits not classified elsewhere.
Potatoes.
Tomatoes.
Truck crops: Sweet corn and all vegetable crops not listed elsewhere.
Field crops:
  1. Field corn.
  2. Oats.
  3. Barley.
  4. Wheat.
  5. Sugar beets.
  6. Rye.
  7. Other field crops not listed elsewhere.
Melons, pickles, cucumbers.
Hay, pasture, and silage: All crops fed to livestock with the exception of field corn.
Cemeteries, parks, and golf courses.
Miscellaneous:
  1. Mint.
  2. Sod.
  3. All other miscellaneous crops not listed elsewhere.

TABLE 1.—*General irrigation data, by county*

County	Systems				Acres					Percent of cropland irrigated
	Total	Municipal	Agricultural	Percent of State total	Total irrigated	Percent of State total	Municipal irrigation	Agricultural irrigation	Cropland in county	
Alcona	2	2	0	0.081	6	0.009	6	0	46,296	0
Alger	0	0	0	0	0	0	0	0	16,330	0
Allegan	99	7	92	3.999	2,626	3,835	64	2,562	231,101	1.1086
Alpena	9	0	9	.363	169	.247	0	169	60,306	.2802
Antrim	12	0	12	.485	436	.637	0	436	58,315	.7476
Arenac	1	0	1	.040	170	.248	0	170	70,832	.2400
Baraga	1	0	1	.040	15	.022	0	15	19,973	.0751
Barry	23	6	17	.929	332	.485	50	282	157,392	.1791
Bay	32	6	26	1.292	1,192	1.741	76	1,116	159,166	.7011
Benzie	17	2	15	.687	390	.570	10	380	25,165	1.5100
Berrien	445	26	419	17.973	9,978	14.571	276	9,702	184,532	5.2576
Branch	13	3	10	.525	416	.607	67	349	177,362	.1967
Calhoun	19	11	8	.767	1,214	1.773	433	781	222,030	.3517
Cass	25	5	20	1.010	830	1.212	32	798	150,396	.5305
Charlevoix	6	1	5	.242	135	.197	70	65	45,605	.1425
Cheboygan	13	3	10	.525	210	.307	15	195	49,601	.3931
Chippewa	2	1	1	.081	10	.015	3	7	102,248	.0068
Clare	7	2	5	.283	16	.023	6	10	51,625	.0193
Clinton	19	2	17	.767	651	.951	5	646	222,931	.2898
Crawford	2	1	1	.081	61	.089	13	48	3,340	1.4371
Delta	3	3	0	.121	9	.013	9	0	61,495	0
Dickinson	10	4	6	.404	336	.491	56	280	20.337	1.3768
Eaton	16	4	12	.646	428	.625	119	309	211,803	.1459
Emmet	20	3	17	.808	445	.650	215	230	48,587	.4734
Genesee	19	8	11	.767	450	.657	109	341	193,155	.1765
Gladwin	0	0	0	0	0	0	0	0	70,477	0
Gogebic	2	1	1	.081	103	.150	3	100	12,571	.7954
Grand Traverse	23	0	23	.929	370	.540	0	370	72,177	.5126
Gratiot	10	2	8	.404	515	.752	4	511	226,531	.2256
Hillsdale	9	2	7	.363	163	.238	66	97	215,796	.0449
Houghton	21	5	16	.848	566	.826	54	512	57,729	.8869
Huron	9	5	4	.363	41	.060	15	26	364,410	.0071
Ingham	25	9	16	1.010	996	1.454	252	744	183,989	4043
Ionia	22	4	18	.888	451	.658	14	437	203,720	.2145
Iosco	2	1	1	.081	92	.134	2	90	41,648	.2160
Iron	7	3	4	.283	236	.345	26	210	20,272	1.0359
Isabella	18	4	14	.727	528	.771	38	490	176,473	.2776
Jackson	23	8	15	.929	1,169	1.707	278	891	196,191	.4541
Kalamazoo	39	12	27	1.575	1,789	2.611	1,176	613	163,083	.3764
Kalkaska	3	0	3	.121	183	.267	0	183	34,950	.5236
Kent	160	14	146	6,462	2,500	3,651	598	1,902	229,816	.8276
Keweenaw	1	1	0	.040	3	.004	3	0	1,608	0
Lake	2	0	2	.081	12	.018	0	12	25,100	.0478
Lapeer	32	1	31	1.292	819	1.196	3	816	220,735	.3696
Leelanau	35	2	33	1.414	450	.657	70	380	52,599	.7224
Lenawee	15	5	10	.606	775	1.132	41	734	302,408	.2428
Livingston	31	10	21	1.252	564	.824	124	440	150,845	.2916
Luce	3	1	2	.121	203	.296	3	200	8,784	2.2768
Mackinac	1	1	0	040	3	.004	3	0	23,277	0
Macomb	79	17	62	3.191	1,864	2.722	568	1,296	134,448	.9639
Manistee	83	4	79	3.352	1,530	2.234	36	1,494	50,354	2.9669
Marquette	4	2	2	.162	40	.058	6	34	21,439	.1585
Mason	21	4	17	.848	467	.682	74	393	81,669	.4812
Mecosta	21	4	17	.848	590	.861	34	556	113,378	.4903
Menominee	6	4	2	.242	38	.055	16	22	93,785	.0234
Midland	4	3	1	.162	325	.474	315	10	87,128	.0114
Missaukee	4	0	4	.162	141	.206	0	141	79,244	.1779
Monroe	30	3	27	1.212	1,577	2.303	15	1,562	218,381	.7153
Montcalm	67	3	64	2.706	2,866	4.185	55	2,811	198,495	1.4162
Montmorency	5	0	5	.202	120	.175	0	120	20,671	.5805
Muskegon	62	17	45	2.504	2,144	3.131	496	1,648	61,460	2.6814
Newaygo	37	4	33	1.494	949	1.386	20	929	106,764	.8710
Oakland	66	42	24	2.666	1,990	2.906	1,592	398	160,313	.2482
Oceana	22	1	21	.888	575	.840	20	555	95,373	.5819
Ogemaw	1	1	0	.040	3	.004	3	0	59,279	0
Ontonagon	1	1	0	.040	3	.004	3	0	39,361	0
Osceola	6	1	5	.242	118	.172	5	113	104,163	1084
Oscoda	1	0	1	.040	12	.018	0	12	15,919	.0753
Otsego	2	0	2	.081	10	.015	0	10	27,833	.0359
Ottawa	215	7	208	8.683	2,514	3.671	246	2,268	170,443	1.3306
Presque Isle	8	0	8	.323	162	.237	0	162	60,423	.2681
Roscommon	3	3	0	.121	9	.013	9	0	5,418	0
Saginaw	18	10	8	.727	398	.581	258	140	279,984	.0500
Salinac	5	2	3	.202	40	.058	6	34	405,767	.0083
Schoolcraft	4	3	1	.162	69	.101	9	60	12,093	.4961
Shiawassee	13	3	10	.525	217	.317	7	210	209,752	.1001
St. Clair	12	7	5	.485	745	1.088	519	226	227,493	.0993
St. Joseph	28	4	24	1.131	1,618	2.363	72	1,546	172,644	.8954
Tuscola	12	1	11	.485	328	.479	3	325	290,749	.1117
Van Buren	215	2	213	8.683	6,754	9,863	16	6,738	168,686	3.9940
Washtenaw	29	14	15	1.171	579	.846	196	383	227,890	.1682
Wayne	77	25	52	3.111	6,492	9.480	4,264	2,228	76,464	2.9137
Wexford	7	2	5	.283	138	.202	68	70	57,736	.1212
State	2,476	385	2,091	100	68,481	100	13,338	55,143	9,79,911	.5639

TABLE 2.—*County summary—Size and number of systems*

County	Acres								Total systems
	½ to 4½	5 to 9½	10 to 19½	20 to 29½	30 to 49½	50 to 74½	75 to 99½	100 and over	
1. Alcona	2								2
2. Alger [1]									0
3. Allegan	12	12	25	9	28	10	1	2	99
4. Alpena	2	2		2	3				9
5. Antrim	2	2	3	2	1		1	1	12
6. Arenac								1	1
7. Baraga			1						1
8. Barry	9	6	4	1	1	1		1	23
9. Bay	6	3	5	1	6	4	6	1	32
10. Benzie	5	3	3	3		1	1	1	17
11. Berrien	61	74	136	70	60	24	8	12	445
12. Branch	2		3	1	3	4			13
13. Calhoun	8	1	1	1	1	2	1	4	19
14. Cass	4	1	4	7	4	2	2	1	25
15. Charlevoix		3		2		1			6
16. Cheboygan	5	5		1	1			1	13
17. Chippewa	1	1							2
18. Clare	6	1							7
19. Clinton	4	1	5	1	4	2		2	19
20. Crawford			1		1				2
21. Delta	3								3
22. Dickinson	2			3	2	2	1		10
23. Eaton	6	2		2	2	2	2		16
24. Emmet	4	4	6	1	2	1	1	1	20
25. Genesee	1	8	4	1	2	2		1	19
26. Gladwin [1]									0
27. Gogebic	1							1	2
28. Grand Traverse	4	6	8	2	2			1	23
29. Gratiot	2		1	1	2	3		1	10
30. Hillsdale	2	3	1	1	1	1			9
31. Houghton	7	5	5		1	1		2	21
32. Huron	6	2	1						9
33. Ingham	9	2	3	4	2	1	2	2	25
34. Ionia	5	4	3	5	1	2	2		22
35. Iosco	1						1		2
36. Iron	2			2		2	1		7
37. Isabella	1	2	4	5	1	4		1	18
38. Jackson	4	2	2	2	3	4	1	5	23
39. Kalamazoo	6	11	7	5	5	1		4	39
40. Kalkaska		1					1	1	3
41. Kent	52	33	28	21	13	8	3	2	160
42. Keweenaw	1								1
43. Lake	1		1						2
44. Lapeer	2	8	8	7	2	2	2	1	32
45. Leelanau	12	7	10	3	1	1	1		35
46. Lenawee	2	3	3	2	2	1		2	15
47. Livingston	12	4	6	2	4	1	1	1	31
48. Luce	1							2	3
49. Mackinac	1								1
50. Macomb	7	13	27	13	9	4	2	4	79
51. Manistee	16	25	11	9	14	7		1	83
52. Marquette	3				1				4
53. Mason	4	4	2	4	5	1	1		21
54. Mecosta	3	4	3	2	5	2	2		21
55. Menominee	4	1		1					6
56. Midland			2			1		1	4
57. Missaukee	1		1		1		1		4
58. Monroe	3	6	2		2	9	5	3	30
58. Montcalm	9	5	7	12	14	6	6	8	67
60. Montmorency	3					2			5
61. Muskegon	6	9	14	7	10	10	3	3	62
62. Newaygo	6	2	13	6	7			3	37
63. Oakland	22	6	7	5	12	7		7	66
64. Oceana	2	4	5	5	4	1		1	22
65. Ogemaw	1								1
66. Ontonagon	1								1
67. Osceola	1	2			3				6
68. Oscoda			1						1
69. Otsego	1	1							2
70. Ottawa	73	46	58	20	13	3	2		215
71. Presque Isle	1	1	3	1	1	1			8
72. Roscommon	3								3
73. Saginaw	4	5	4		2	2		1	18
74. Sanilac	3		1	1					5
75. Schoolcraft	3					1			4
76. Shiawassee	7	2	1	2				1	13
77. St. Clair	2	1		1	2	2	2	2	12
78. St. Joseph	4	5	1	2	3	6		7	28
79. Tuscola	2	5			3	1		1	12
80. Van Buren	19	22	54	45	44	17	4	10	215
81. Washtenaw	12	4	4	2	3	3		1	29
82. Wayne	5	4	5	27	6	17	5	8	77
83. Wexford	2	1	1	1	1	1			7
Total, 83 counties	512	400	519	336	326	194	72	117	2,476

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[1] No irrigation at present.

TABLE 3.—*Acres irrigated, by*

County	Year unknown	Prior to 1930	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
Alcona	6														
Alger															
Allegan	116	210	220					242		363			480		523
Alpena															
Antrim															
Arenac															
Baraga															
Barry		7	39		41			52					59		61
Bay		64													
Benzie		25		85		88									
Berrien	459	493	506		649	741	813	815	1,044	1,099		1,139	1,444	1,464	1,554
Branch	10	64												219	
Calhoun	132	243			248										
Cass	45	77								97					
Charlevoix		70													78
Cheboygan		15			23									123	
Chippewa	10														
Clare	2	6									7				
Clinton	4	5													
Crawford		48											61		
Delta	3	6													9
Dickinson	50	56													
Eaton		67								117					
Emmet	5	72		74									174	198	
Genesee		52													
Gladwin															
Gogebic		3						103							
Grand Traverse															
Gratiot		1						3							
Hillsdale	9	69	71										77		
Houghton	3	54													
Huron	24	36													
Ingham	199	250											251		
Ionia		2								23					
Iosco															
Iron	3	26									116				
Isabella		24		31											
Jackson	16	269	275					278							
Kalamazoo	122	1,157	1,250			1,255	1,261		1,265				1,367		1,402
Kalkaska															
Kent	60	746	918		967	975	992	1,111		1,131	1,151	1,165	1,279	1,293	1,316
Keweenaw	3														
Lake															
Lapeer	7	44								121					139
Leelanau		65		72					94					106	
Lenawee	5	20						23							
Livingston	24	126					136		140						
Luce	3														
Mackinac	3														
Macomb	51	333			363	369		439					444		
Manistee	31						84				111		151		
Marquette	3							6							
Mason	1	20									30				
Mecosta			20				30						33		
Menominee	7	10							16						
Midland									65						
Missaukee															
Monroe	88	94									102				
Montcalm	164	167													
Montmorency															
Muskegon	186	281	346	355	440	465		639				642			660
Newaygo		10													
Oakland	237	1,356	1,462		1,486					1,526	1,528		1,576		
Oceana		20	67												
Ogemaw								3							
Ontonagon	3														
Osceola											5				
Oscoda															
Otsego															
Ottawa	100	161	213	224	236		250	297	305	317	335	347	382	383	
Presque Isle															
Roscommon	3														
Saginaw	70	130			250			264							
Sanilac		6													
Schoolcraft	63	66								69					
Shiawassee	3														
St. Clair		212						214			229				
St. Joseph	208	427		433								452			
Tuscola	3														
Van Buren	116		117				156	191		201			323		362
Washtenaw		19	58		123		158		218	220					
Wayne	580	4,188	4,238	4,270	4,335	4,367	4,439	4,526	4,541	4,641	4,656	4,721	4,901	5,019	5,069
Wexford	32	100													

years—Accumulative total

County	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
Alcona																
Alger																
Allegan	575		718	806	946	1, 179	1, 242	1, 468	1, 757	1, 844	2, 197	2, 370	2, 472	2, 574	2, 626	
Alpena						1							72	169		
Antrim			287	290	308	333			358	361			371	431	436	
Arenac										170						
Baraga															15	
Barry							121	126		129	149	150	166	323	332	
Bay			99	224	260	396		411	503	728		802	821	935	1, 112	1, 192
Benzie				215	222		235		329		344		361	390		
Berrien		1, 572	1, 814	2, 867	3, 502	4, 002	4, 442	5, 233	5, 656	6, 337	7, 093	7, 984	8, 414	,508	9, 978	
Branch			284	362		402				405			406	416		
Calhoun		261						453	608		658			1, 214		
Cass							247	380		415	535		697	830		
Charlevoix		98					104	129					135			
Cheboygan				147		155	158			204		206	210			
Chippewa																
Clare							8		14					15	16	
Clinton					14	79	299	331	461	479	572		602	650		
Crawford																
Delta																
Dickinson				56						12	146	206		316	336	
Eaton				138		213	215	301	309	396	400	408		428		
Emmet		223		227		261		301	307			382	3 4	444		
Genesee				127	154			164		289	291	338	398	405	450	
Gladwin																
Gogebic																
Grand Traverse					105	127	128	151	165		179		204	243	69	
Gratiot										268		336	383	453	515	
Hillsdale						134		142						163		
Houghton					412	478		506	527	544	554	559		561	566	
Huron			41													
Ingham				252		292		672			809	918	995			
Ionia		95		137	138	149		240		253	260	263	271	368	451	
Iosco				2				92								
Iron					166		216								236	
Isabella					51		76	176	191	291	311	395	509	521	528	
Jackson		318	421	621	696		782			902	942	1, 112	1, 135		1, 169	
Kalamazoo		1, 434	1, 444			1, 519		1, 576			1, 614	1, 774	1, 784	1, 788		
Kalkaska			100					175		183						
Kent	1, 319	1, 375	1, 508	1, 737	1, 828	1, 912	2, 049	2, 143	2, 186	2, 285	2, 291	2, 389	2, 500			
Keweenaw																
Lake				2						12						
Lapeer			164		172	292	302	438		450	530	555	572	802	819	
Leelanau			138		162			289	291	295	308	327	390	449		
Lenawee				28			48		108	146	186	736	775			
Livingston		141				173		280	326	487	546	549		564		
Luce							103					203				
Mackinac																
Macomb			452	462	557	602	621	804	1, 043	1, 358	1, 500	1, 592	1, 756	1, 802	1, 864	
Manistee			185	332		337	414	631	673	723	857	1, 011	1, 228	1, 508	1, 529	
Marquette									10						49	
Mason				85					165		246	286	346	362	437	467
Mecosta				73		93		226	318	326	353	428	438	491	590	
Menominee						18					38					
Midland												75		315		325
Missaukee				18	138				141							
Monroe			110			150		305	404		574	1, 056	1, 236	1, 486	1, 577	
Montcalm		187	332	660	968	1, 290	1, 454	1, 473		1, 553	1, 626	2, 015	2, 638	2, 866		
Montmorency								58						119		
Muskegon			679		684	741		761	853		1, 105	1, 350	1, 821	1, 952	2, 144	
Newaygo				40		85	240	356	414	520		580	771	894		949
Oakland			1, 577	1, 602	1, 639			1, 649	1, 654	1, 728	1, 748	1, 814	1, 826	1, 915	1, 990	
Oceana						117	293	339	385	470	497	504	573		575	
Ogemaw																
Ontonagon																
Osceola						72							115		118	
Oscoda														12		
Otsego								3						10		
Ottawa	386	427	631	733	1, 004	1, 052	1, 265	1, 441	1, 545	1, 666	1, 780	1, 916	2, 295	2, 463	2, 513	
Presque Isle				77		92		142	152				162			
Roscommon				6		9										
Saginaw								265		272	290	350	392	398		
Sanilac												26				40
Schoolcraft																
Shiawassee				14		22		27	47	49		52	213	216		
St. Clair						334		424				465	520	630	745	
St. Joseph			490			520	560	588	638	765	1, 055	1, 267	1, 542		1, 612	1, 618
Tuscola						11			51	235		243	314	322		328
Van Buren	456	776	977	1, 279	1, 971	2, 784	3, 522	4, 021	4, 485	4, 570	4, 938	5, 500	5, 908	6, 754		
Washtenaw				223	366			376		416	441	516	527	572	579	
Wayne	5, 134	5, 149	5, 239	5, 339	5, 358	5, 538	5, 604	5, 822	5, 846	5, 941	6, 006	6, 275	6, 343	6, 395	6, 492	
Wexford						118								138		

TABLE 4.—*Irrigation water withdrawals, by river basins*

Basin	Total		Surface		Ground		Combined		City	
	Systems	Acres	Systems	Acres	Systems	Acres	Systems	Acres	Systems	Acres
Montreal	1	3							1	3
Ontonagon	2	103	1	100					1	3
Portage	17	478½	11	405½	2	22			4	51
Sturgeon (Houghton)	4	95½	3	91	1	4½				
Chocolay	1	4	1	4						
Tahquamenon	2	103			2	103				
Manistique	5	169	4	166	1	3				
Days	1	3	1	3						
Escanaba	1	3							1	3
Menominee	21	601	14	536					7	65
Galien	35	620	23	500	7	96			5	24
St. Joseph	347	10,380	211	5,539	110	4,125	10	424	16	292
Paw Paw	285	6,970	165	3,375	94	2,545	25	1,049	1	1
Black (South Haven)	113	3,255	70	1,924	39	1,239	3	82	1	10
Kalamazoo	104	4,268	44	1,404	41	1,299	9	1,208	10	357
Black (Holland)	83	881	16	155	54	509	5	94	8	123
Grand	522	11,980	235	6,626	252	4,232	23	875	12	247
Muskegon	72	1,775	38	913	21	415	2	137	11	310
White	14	352	12	307	1	30			1	15
Pentwater	24	575	15	328	5	146	2	73	2	28
Pere Marquette	15	374	8	294	7	80				
Lincoln	7	116	5	97					2	19
Big Sable	3	135			2	110	1	25		
Manistee	80	1,669	48	1,081	27	551	1	1	4	36
Betsie	7	77	3	28	3	24	1	25		
Boardman	8	75	6	48	2	27				
Elk	10	109	8	91	2	18				
Jordan	5	208	1	6	3	132	1	70		
Boyne	4	254	3	53	1	201				
Cheboygan	21	308	11	209	9	97	1	2		
Ocqueoc	1	6			1	6				
Thunder Bay	10	234	6	58	4	176				
Au Sable	7	176	3	141	3	22			1	13
Au Gres	1	170	1	170						
Rifle	1	3	1	3						
Kawkawlin	1	6	1	6						
Tittabawassee	46	1,763	36	1,415	5	193			5	155
Shiawassee	23	361	13	324	7	30	1	5	2	2
Flint	37	878	28	712	7	142			2	24
Cass	14	277	9	121	3	48	1	105	1	3
Saginaw	17	256	4	61	2	15			11	180
Willow	1	3			1	3				
Black (Port Huron)	16	731	13	513					3	218
Pine (St. Clair)	3	133	1	90	1	41			1	2
Belle	12	362	11	355			1	7		
Clinton	102	2,289	82	1,876	8	199	4	45	8	169
Rouge	75	3,241	42	2,203	9	603	2	25	22	593
Huron	71	1,550	47	1,293	19	189	4	62	1	6
Stoney Creek	9	330	3	183	6	147				
Raisin	18	904	10	741	6	82	1	80	1	1
Maumee	3	64	2	59	1	5				
Small watersheds leading to the Great Lakes	171	8,170	87	2,342	60	2,104	6	202	18	3,522

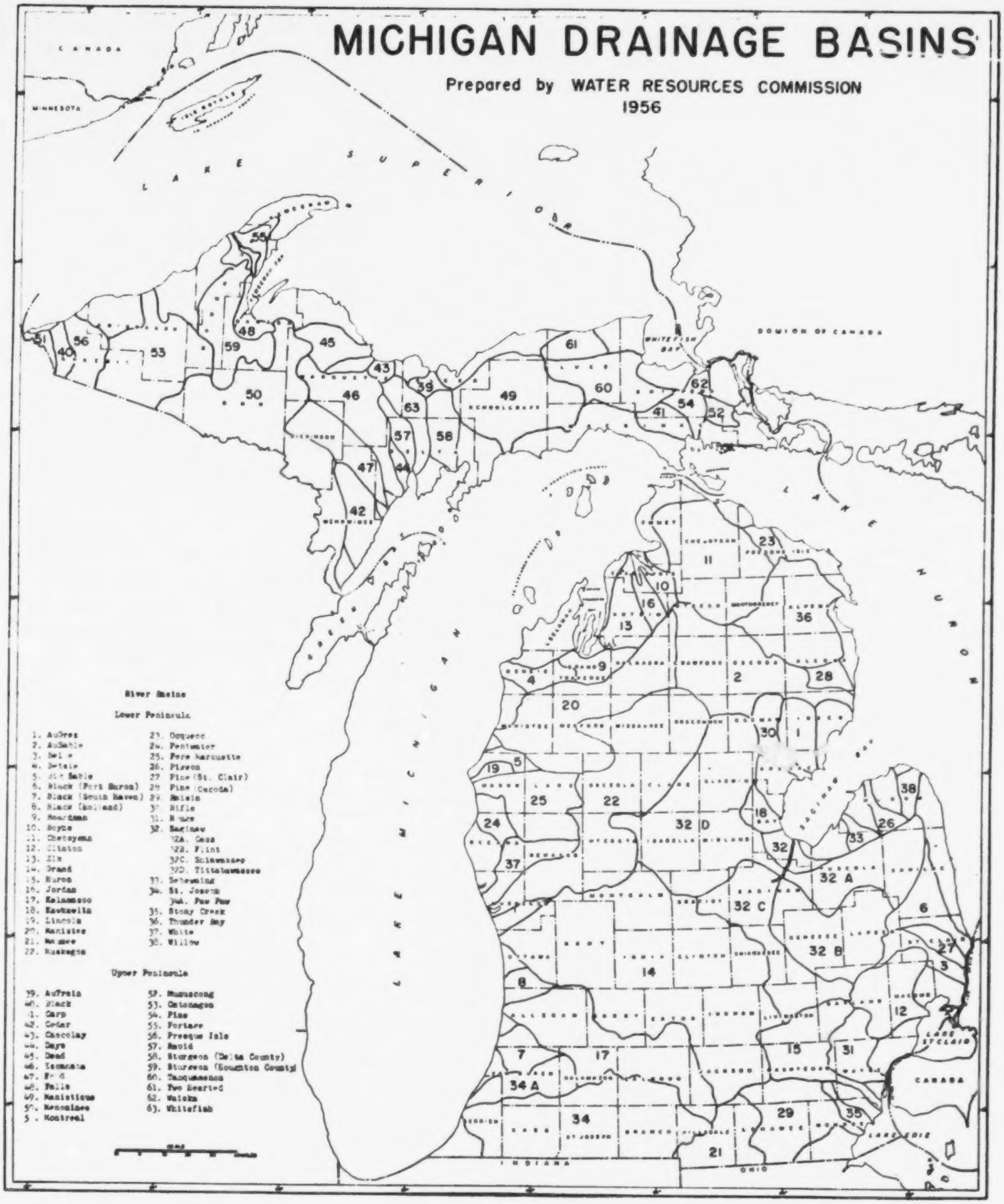
MICHIGAN DRAINAGE BASINS
Prepared by WATER RESOURCES COMMISSION
1956
CANADA
MINNESOTA
ISLE ROYALE
LAKE SUPERIOR
WHITEFISH BAY
DOMINION OF CANADA
LAKE MICHIGAN
LAKE HURON
SAGINAW BAY
LAKE ST. CLAIR
CANADA
LAKE ERIE
INDIANA
OHIO
River Basins
Lower Peninsula
1. AuGres
2. AuSable
3. Belle
4. Betsie
5. Big Sable
6. Black (Port Huron)
7. Black (South Haven)
8. Black (Holland)
9. Boardman
10. Boyne
11. Cheboygan
12. Clinton
13. Elk
14. Grand
15. Huron
16. Jordan
17. Kalamazoo
18. Kawkawlin
19. Lincoln
20. Manistee
21. Maumee
22. Muskegon
23. Ocqueoc
24. Pentwater
25. Pere Marquette
26. Pigeon
27 Pine (St. Clair)
28 Pine (Alcona)
29. Raisin
30. Rifle
31. Rouge
32. Saginaw
32A. Cass
32B. Flint
32C. Shiawassee
32D. Tittabawassee
33. Sebewaing
34. St. Joseph
34A. Paw Paw
35. Stony Creek
36. Thunder Bay
37. White
38. Willow
Upper Peninsula
39. AuTrain
40. Black
41. Carp
42. Cedar
43. Chocolay
44. Days
45. Dead
46. Escanaba
47. Ford
48. Falls
49. Manistique
50. Menominee
51. Montreal
52. Munuscong
53. Ontonagon
54. Pine
55. Portage
56. Presque Isle
57. Rapid
58. Sturgeon (Delta County)
59. Sturgeon (Houghton County)
60. Tahquamenon
61. Two Hearted
62. Waiska
63. Whitefish

TABLE 5.—*Great Lakes irrigation water withdrawals, Lower and Upper Peninsulas, Mich.*

County	Number of systems	Number of acres
Berrien	1	5
Leelanau	10	122
Grand Traverse	2	62
Wayne	1	100
Ottawa	1	16
Muskegon	1	25
St. Clair	1	90
Huron	2	8
Alcona	1	3
Menominee	2	9
Chippewa	1	7
Total	23	447

TABLE 6.—*Summary of irrigation water withdrawals*

	Total		Surface		Ground		Combined		City	
	Systems	Acres	Systems	Acres	Systems	Acres	Systems	Acres	Systems	Acres
Upper Peninsula, excluding Great Lakes and small watersheds	55	1,563	35	1,305½	6	132½			14	125
Lower Peninsula, excluding Great Lakes and small watersheds	2,227	58,301	1,235	33,302	763	17,777	98	4,394	131	2,828
Great Lakes	23	447	23	447						
Small watersheds leading to the Great Lakes	171	8,170	87	2,342	60	2,104	6	202	18	3,522
Total	2,476	68,481	1,380	37,396½	829	20,013½	104	4,596	163	6,475

TABLE 7.—*Statewide average application raters with projected totals*

[Average application on 68,500 acres = 4.28 inches per year]

Crops irrigated	Acres irrigated	Average inches of water per year	Total acre-inches per year	Cubic feet total per year
Flowers and nurseries	4,794	6	28,764	104,413,320
Strawberries	6,796	[1] 1 [2] 3	6,796 20,388	24,669,480 74,008,440
Raspberries	1,414	3½	4,949	17,964,870
Blueberries	1,732	4	6,928	25,148,640
Tree fruits	5,491	3½	19,218	69,761,340
Other small fruit	30	4½	135	490,050
Potatoes	8,854	5	44,270	160,700,100
Tomatoes	2,144	4	8,576	31,130,880
Truck crops	11,598	4½	52,191	189,453,330
Field crops	4,098	3½	14,343	52,065,090
Melons, cucumbers, and pickles	3,791	4½	17,060	61,927,800
Hay, pasture, and silage	2,151	4½	9,680	35,138,400
Cemeteries, parks, and golf courses	13,336	4	53,344	193,638,720
Miscellaneous	2,252	3	6,756	24,524,280
Total	68,481		293,398	[3] 1,065,034,740

NOTE.—Inches of water per year—average application during years of normal precipitation. Data based on information from irrigators contacted during water resources commission field surveys. Above figures are rounded off to the nearest ½ inch.

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[1] Frost.

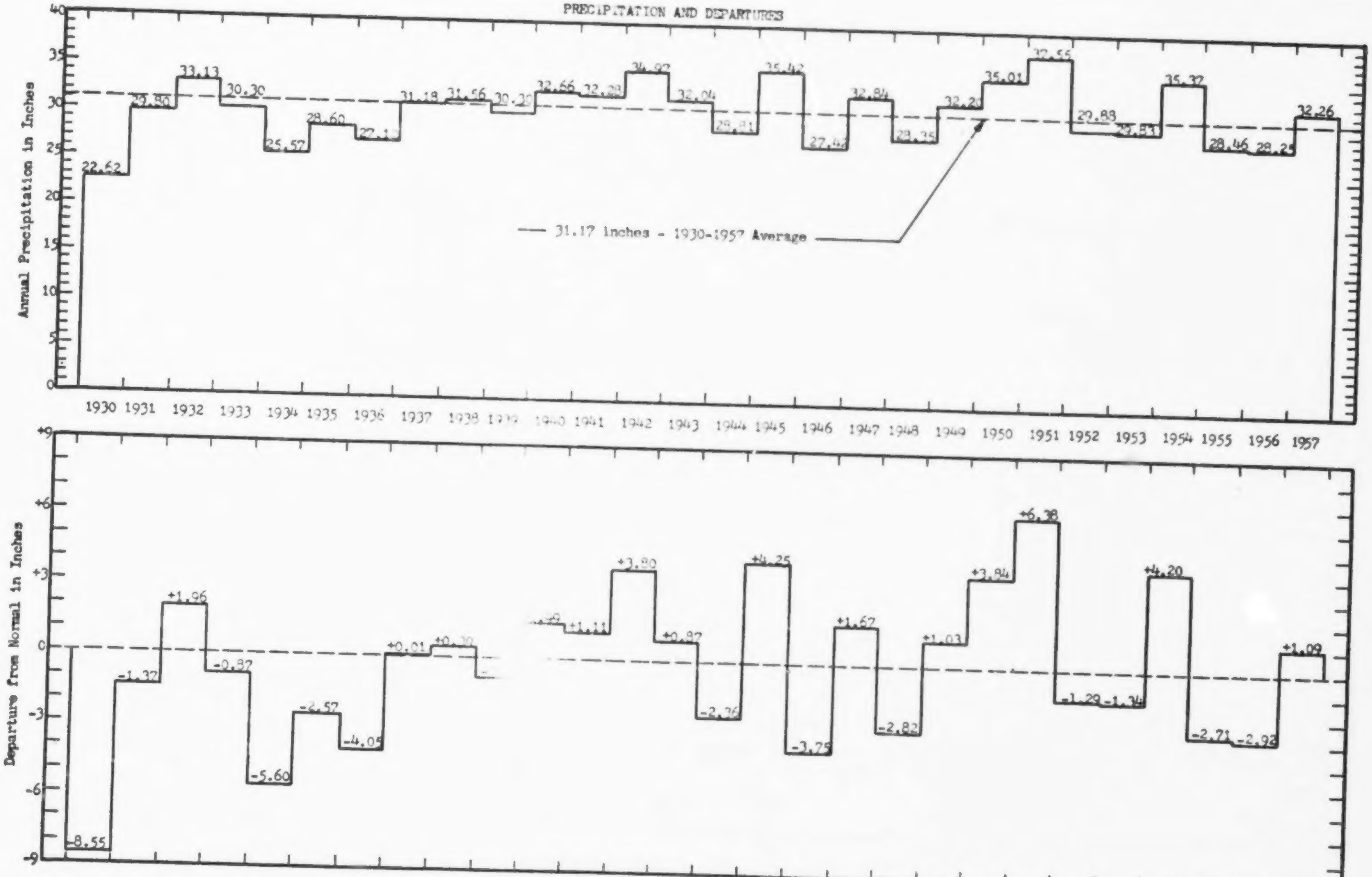
[2] Drought.

[3] Equal to 112.06 c.f.s. per 110 days or 33.8 c.f.s. per year.

TABLE 8

ANNUAL

PRECIPITATION AND DEPARTURES

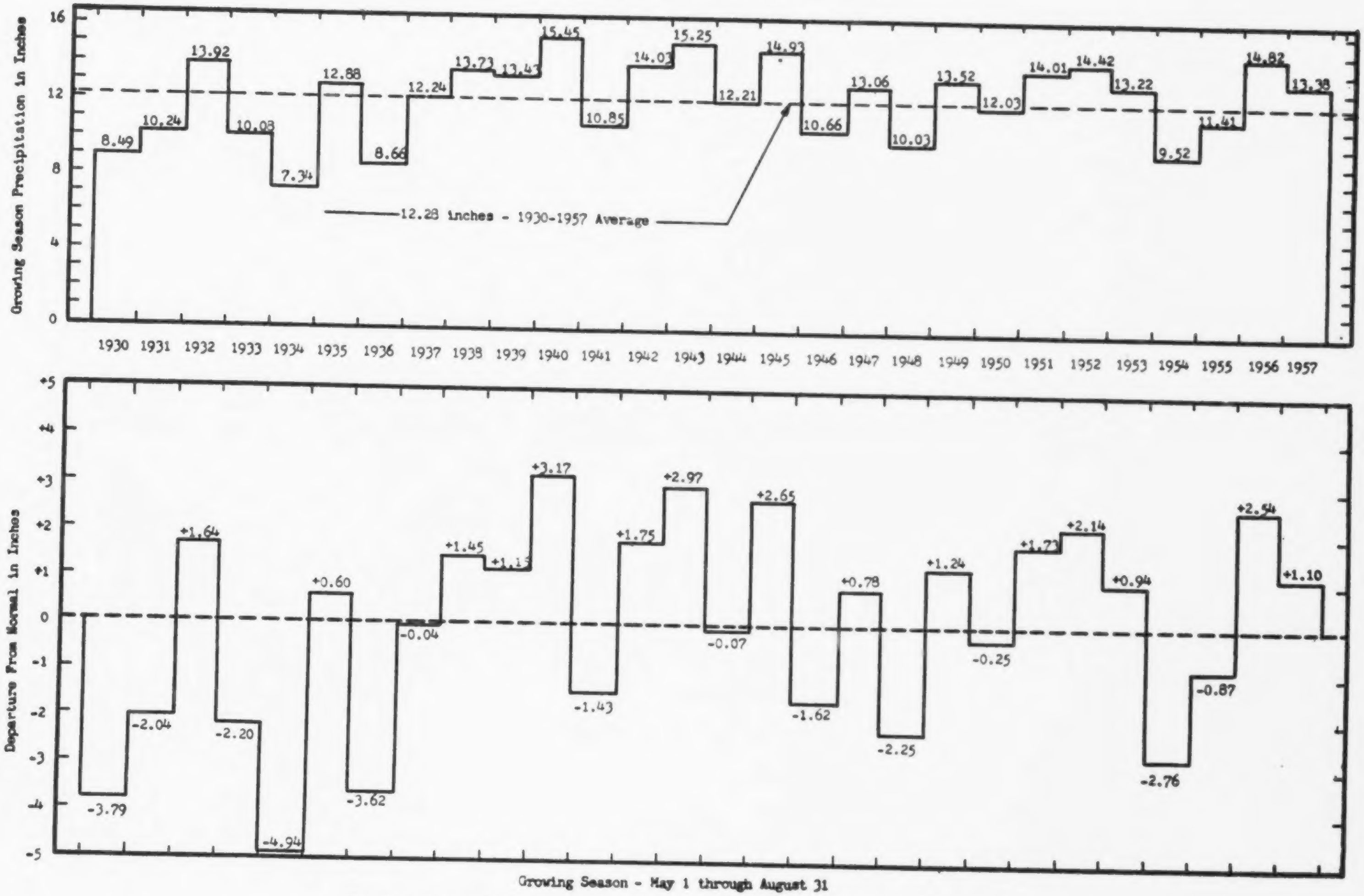


The Average Precipitation is 31.17 inches. (Based on 1930 to 1957 records)

TABLE 9

GROWING SEASON

PRECIPITATION AND DEPARTURES



Growing Season - May 1 through August 31

Normal growing season precipitation is 12.28 inches. (Based on 1930 to 1957 records)

TABLE 10.—*Initial acres of crops, by years*

Crop	Year unknown	Prior to 1930	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939
Flowers and nurseries	1,066	217	211	42	4	6	53	102	146	37	39	16
Strawberries	96	41	9	2	18	12	21	31	31	31	1	16
Raspberries	21	5	----	----	----	6	13	----	4	7	----	3
Blueberries	60	----	----	----	3	----	39	----	----	----	16	----
Tree fruits	175	----	----	60	128	72	10	----	20	20	----	----
Other small fruit	----	----	----	----	----	----	----	----	----	----	----	----
Potatoes	146	50	33	----	----	----	38	12	12	20	90	----
Tomatoes	8	16	8	----	1	----	----	19	13	5	----	----
Truck crops	709	590	216	13	176	8	23	250	24	184	20	44
Field crops	215	----	----	----	----	----	----	----	10	----	----	----
Melons, pickles, and cucumbers	19	4	2	----	----	2	14	3	1	28	----	----
Hay, pasture and silage	35	----	----	----	----	----	----	20	----	----	----	----
Cemeteries, parks, and golf courses	152	8,065	325	17	256	85	117	260	152	198	45	74
Miscellaneous	570	----	6	----	----	----	----	----	----	----	----	----
Total	3,272	8,988	710	134	586	191	328	697	413	530	211	153

Crop	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Flowers and nurseries	138	180	37	52	68	106	209	198	277	161	390
Strawberries	61	4	20	10	84	215	505	264	346	505	693
Raspberries	9	1	11	----	28	41	103	66	105	57	60
Blueberries	49	6	----	45	3	30	26	88	53	174	58
Tree fruits	250	106	7	12	----	96	450	284	410	200	401
Other small fruit	----	----	2	----	----	1	----	----	----	----	13
Potatoes	----	----	20	1	134	705	754	953	616	420	433
Tomatoes	4	----	38	----	8	14	192	136	206	80	276
Truck Crops	140	95	70	2	127	328	508	581	590	775	899
Field crops	----	----	----	----	70	126	163	121	196	155	350
Mellons, pickles, and cucumbers	15	----	3	2	53	99	204	119	151	289	109
Hay, pasture, and silage	50	----	8	25	30	35	113	40	113	107	110
Cemeteries, parks and golf courses	482	53	113	68	68	121	53	108	361	51	786
Miscellaneous	----	----	----	----	----	2	59	336	81	162	330
Total	1,198	444	329	217	673	1,919	3,339	3,294	3,505	3,036	4,908

Crop	1951	1952	1953	1954	1955	1956	1957	1958	Total
Flowers and nurseries	154	64	218	431	102	135	34	1.25	4,794.25
Strawberries	439	422	469	722	662	898	146	22.00	6,796.00
Raspberries	73	95	136	149	139	210	68	3.75	1,413.75
Blueberries	79	6	143	71	540	199	34	10.00	1,732.00
Tree fruits	386	396	265	238	474	782	217	32.75	5,490.75
Other small fruit	----	----	----	----	4	4	6	----	30.00
Potatoes	272	977	274	1,276	653	651	265	48.50	8,853.50
Tomatoes	190	127	131	188	87	230	161	6.00	2,144.00
Truck crops	650	579	805	971	1,003	897	281	40.50	11,598.50
Field crops	232	424	452	575	402	372	215	20.50	4,098.50
Melons, pickles, and cucumbers	165	233	316	407	525	890	227	10.50	3,790.50
Hay, pasture, and silage	65	194	259	325	277	340	----	5.00	2,151.00
Cemeteries, parks, and golf courses	66	80	170	316	33	271	380	10.25	13,336.25
Miscellaneous	129	182	85	62	93	52	103	.25	2,252.25
Total	2,900	3,779	3,723	5,731	4,994	5,931	2,137	211.25	68,481.25

Table 11.—*Total acres of crops, by years*

Crop	Year unknown	Prior 1930	1930	1931	1932	1933	1934	1935
Flowers and nurseries	1,066	1,283	1,394	1,436	1,440	1,446	1,499	1,601
Strawberries	96	137	146	148	166	178	190	230
Raspberries	21	26	26	26	26	32	45	45
Blueberries	60	60	60	60	63	63	102	102
Tree fruits	175	175	175	235	363	435	445	445
Other small fruit								
Potatoes	146	196	229	229	229	229	267	279
Tomatoes	8	24	32	32	33	33	33	52
Truck crops	709	1,299	1,515	1,528	1,704	1,712	1,735	1,985
Field crops	215	215	215	215	215	215	215	215
Melons, pickles, and cucumbers	19	23	25	25	25	27	41	44
Hay, pasture, and silage	35	35	35	35	35	35	35	55
Cemeteries, parks, and golf courses	152	8,217	8,542	8,559	8,815	8,900	9,017	9,277
Miscellaneous	570	570	576	576	576	576	576	576
Total	3,272	12,260	12,970	13,104	13,690	13,881	14.209	14,906

Crop	1936	1937	1938	1939	1940	1941	1942	1943
Flowers and nurseries	1,747	1,784	1,823	1,839	1,977	2,157	2,194	2,246
Strawberries	261	292	293	309	370	374	394	404
Raspberries	49	56	56	59	68	69	80	80
Blueberries	102	102	118	118	167	173	173	218
Tree fruits	465	485	485	485	735	840	847	859
Other small fruit							2	2
Potatoes	291	311	401	401	401	401	421	422
Tomatoes	65	70	70	70	74	74	112	112
Truck crops	2,009	2,193	2,213	2,257	2,397	2,492	2,562	2,564
Field crops	225	225	225	225	225	225	225	225
Melons, pickles, and cucumbers	45	73	73	73	88	88	91	93
Hay, pasture, and silage	55	55	55	55	105	105	113	138
Cemeteries, parks, and golf courses	9,429	9,627	9,672	9,746	10,228	10,281	10,394	10,462
Miscellaneous	576	576	576	576	576	576	576	576
Total	15,319	15,849	16,060	16,213	17,411	17,855	18,184	18,401

Crop	1944	1945	1946	1947	1948	1949	1950	1951
Flowers and nurseries	2,314	2,420	2,629	2,827	3,104	3,265	3,655	3,809
Strawberries	488	703	1,208	1,472	1,818	2,323	3,016	3,455
Raspberries	108	149	252	318	423	480	540	613
Blueberries	221	251	277	365	418	592	650	729
Tree fruits	859	955	1,405	1,689	2,099	2,299	2,700	3,086
Other small fruit	2	3	3	3	3	3	16	16
Potatoes	556	1,261	2,015	2,968	3,584	4,004	4,437	4,709
Tomatoes	120	134	326	462	668	748	1,024	1,214
Truck crops	2,691	3,019	3,527	4,108	4,698	5,473	6,372	7,022
Field crops	295	421	584	705	901	1,056	1,406	1,638
Melons, pickles, and cucumbers	146	245	449	568	719	908	1,017	1,182
Hay, pasture, and silage	168	203	316	356	469	576	686	751
Cemeteries, parks, and golf courses	10,530	10,651	10,704	10.812	11,173	11,224	12,010	12,076
Miscellaneous	576	578	637	973	1,054	1,216	1,546	1,675
Total	19,074	20,993	24,332	27,626	31,131	34,167	39,075	41,975

Crop	1952	1953	1954	1955	1956	1957	Total, 1958	Portion of irrigated land
								Percent
Flowers and nurseries	3,873	4,091	4,522	4,624	4,759	4,793	4,794.25	7.00
Strawberries	3,877	4,346	5,068	5,730	6,628	6,774	6,796.00	9.92
Raspberries	708	844	993	1,132	1,342	1,410	1,413.75	2.07
Blueberries	735	878	949	1,489	1,688	1,722	1,732.00	2.53
Tree fruits	3,482	3,747	3,985	4,459	5,241	5,458	5,490.75	8.02
Other small fruit	16	16	16	20	24	30	30.00	.04
Potatoes	5,686	5,960	7,236	7,889	8,540	8,805	8,853.50	12.93
Tomatoes	1,341	1,472	1,660	1,747	1,977	2,138	2,144.00	3.13
Truck crops	7,601	8,406	9,377	10,380	11,277	11,558	11,598.50	16.94
Field crops	2.062	2,514	3,089	3,491	3,863	4,078	4,098.50	5.98
Melons, pickles, and cucumbers	1,415	1,731	2,138	2,663	3,553	3,780	3,790.50	5.54
Hay, pasture, and silage	945	1,204	1,529	1,806	2,146	2,146	2,151.00	3.14
Cemeteries, parks, and golf courses	12,156	12,326	12,642	12,675	12,946	13,326	13,336.25	19.47
Miscellaneous	1,857	1,942	2,004	2,097	2,149	2,252	2,252.25	3.29
Total	45,754	49,477	55,208	60,202	66,133	68,270	68,481.25	100.00

TABLE 12.—*Initial yearly number and types of systems*

Type of system	Year unknown	Prior 1930	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943
Agricultural (farm)	77	53	22	4	11	4	11	22	11	14	5	6	17	4	10	6
Flowers and nurseries	16	10	7	3	1	1	1	2	2	3	3	3	6	8	5	1
Parks, cemeteries, and golf courses	101	151	10	3	5	2	1	13	3	4	2	1	9	------	5	------
Total	194	214	39	10	17	7	13	37	16	21	10	10	32	12	20	7

Type of system	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	Total
Agricultural (farm)	15	49	89	88	93	93	141	110	115	137	159	196	207	66	3	1, 838
Flowers and nurseries	2	8	12	8	17	15	17	5	15	17	24	16	18	6	1	253
Parks, cemeteries, and golf courses	1	5	1	2	6	3	8	3	8	5	6	3	10	12	2	385
Total	18	62	102	98	116	111	166	118	138	159	189	215	235	84	6	2, 476

TABLE 13.—*Total yearly number and types of systems*

Type of system	Year unknown	Prior to 1930	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Agricultural (farm)	77	130	152	156	167	171	182	204	215	229	234	240	257	261	271	277	292	341
Flowers and nurseries	16	26	33	36	37	38	39	41	43	46	49	52	58	66	71	72	74	82
Parks, cemeteries, and golf courses	101	252	262	265	270	272	273	286	289	293	295	296	305	305	310	310	311	316
Total	194	408	447	457	474	481	494	531	547	568	578	588	620	632	652	659	677	739

Type of system	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	Total
Agricultural (farm)	430	518	611	704	845	955	1, 070	1, 207	1, 366	1, 562	1, 769	1, 835	1, 838	1, 838
Flowers and nurseries	94	102	119	134	151	156	171	188	212	228	246	252	253	253
Parks, cemeteries, and golf courses	317	319	325	328	336	339	347	352	358	361	371	383	385	385
Total	841	939	1, 055	1, 166	1, 332	1, 450	1, 588	1, 747	1, 936	2, 151	2, 386	2, 470	2, 476	2, 476

TABLE 14.—*Total yearly number of systems by source of water*

Source of water	Year unknown	Prior 1930	1930	1931	1932	1933	1934	1935	1936	1937
Ground water	26	97	122	127	136	140	146	158	162	173
Surface water	106	186	192	196	199	201	207	225	234	242
City water	62	111	116	117	121	122	122	126	129	129
Combined water	0	14	17	17	18	18	19	22	22	24
Total	194	408	447	457	474	481	494	531	547	568

Source of water	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Ground water	177	182	197	200	205	210	218	243	273	300
Surface water	247	250	263	270	281	283	293	324	389	452
City water	130	131	134	136	139	139	139	140	141	142
Combined water	24	25	26	26	27	27	27	32	38	45
Total	578	588	620	632	652	659	677	739	841	939

Source of water	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	Total
Ground water	344	378	443	477	515	569	633	721	806	828	829	829
Surface water	514	584	673	752	850	942	1, 051	1, 175	1, 314	1, 375	1, 380	1, 380
City water	145	145	148	150	150	153	157	158	162	163	163	163
Combined water	52	59	68	71	73	83	95	97	104	104	104	104
Total	1, 055	1, 166	1, 332	1, 450	1, 588	1, 747	1, 936	2, 151	2, 386	2, 470	2, 476	2, 476

TABLE 15.—*Initial yearly number of systems by source of water*

Source of water	Year unknown	Prior 1930	1930	1931	1932	1933	1934	1935	1936	1937
Ground water	26	71	25	5	9	4	6	12	4	11
Surface water	106	80	6	4	3	2	6	18	9	8
City water	62	49	5	1	4	1		4	3	
Combined water		14	3		1		1	3		2
Total	194	214	39	10	17	7	13	37	16	21

Source of water	1938	1939	1940	1941	1942	1943	1944	1945	1956	1947
Ground water	4	5	15	3	5	5	8	25	30	27
Surface water	5	3	13	7	11	2	10	31	65	63
City water	1	1	3	2	3			1	1	1
Combined water		1	1		1			5	6	7
Total	10	10	32	12	20	7	18	62	102	98

Source of water	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	Total
Ground water	44	34	65	34	38	54	64	88	85	22	1	829
Surface water	62	70	89	79	98	92	109	124	139	61	5	1,380
City water	3		3	2		3	4	1	4	1		163
Combined water	7	7	9	3	2	10	12	2	7			104
Total	116	111	166	118	138	159	189	215	235	84	6	2,476

TABLE 16.—*Average yearly size of systems*

	Year unknown	Prior 1930	1930	1931	1932	1933	1934	1935
Number of systems	194	408	447	457	474	481	494	531
Acres irrigated	3,272	12,260	12,970	13,104	13,690	13,881	14,209	14,906
Average size in acres	16.87	30.05	29.02	28.67	28.88	28.86	28.76	28.07

	1936	1937	1938	1939	1940	1941	1942	1943
Number of systems	547	568	578	588	620	632	652	659
Acres irrigated	15,319	15,849	16,060	16,213	17,411	17,855	18,184	18,401
Average size in acres	28.00	27.90	27.78	27.57	28.08	28.25	27.80	27.89

	1944	1945	1946	1947	1948	1949	1950	1951
Number of systems	677	739	841	939	1,055	1,166	1332	1,450
Acres irrigated	19,074	20,993	24,332	27,626	31,131	34,167	39,075	41,975
Average size in acres	28.17	28.41	28.93	29.42	29.51	29.30	29.34	28.95

	1952	1953	1954	1955	1956	1957	1958 (total)
Number of systems	1,588	1,747	1,936	2,151	2,386	2,470	2,476
Acres irrigated	45,754	49,477	55,208	60,202	66,133	68,270	68,481.25
Average size in acres	28.81	28.32	28.52	27.99	27.72	27.64	27.66

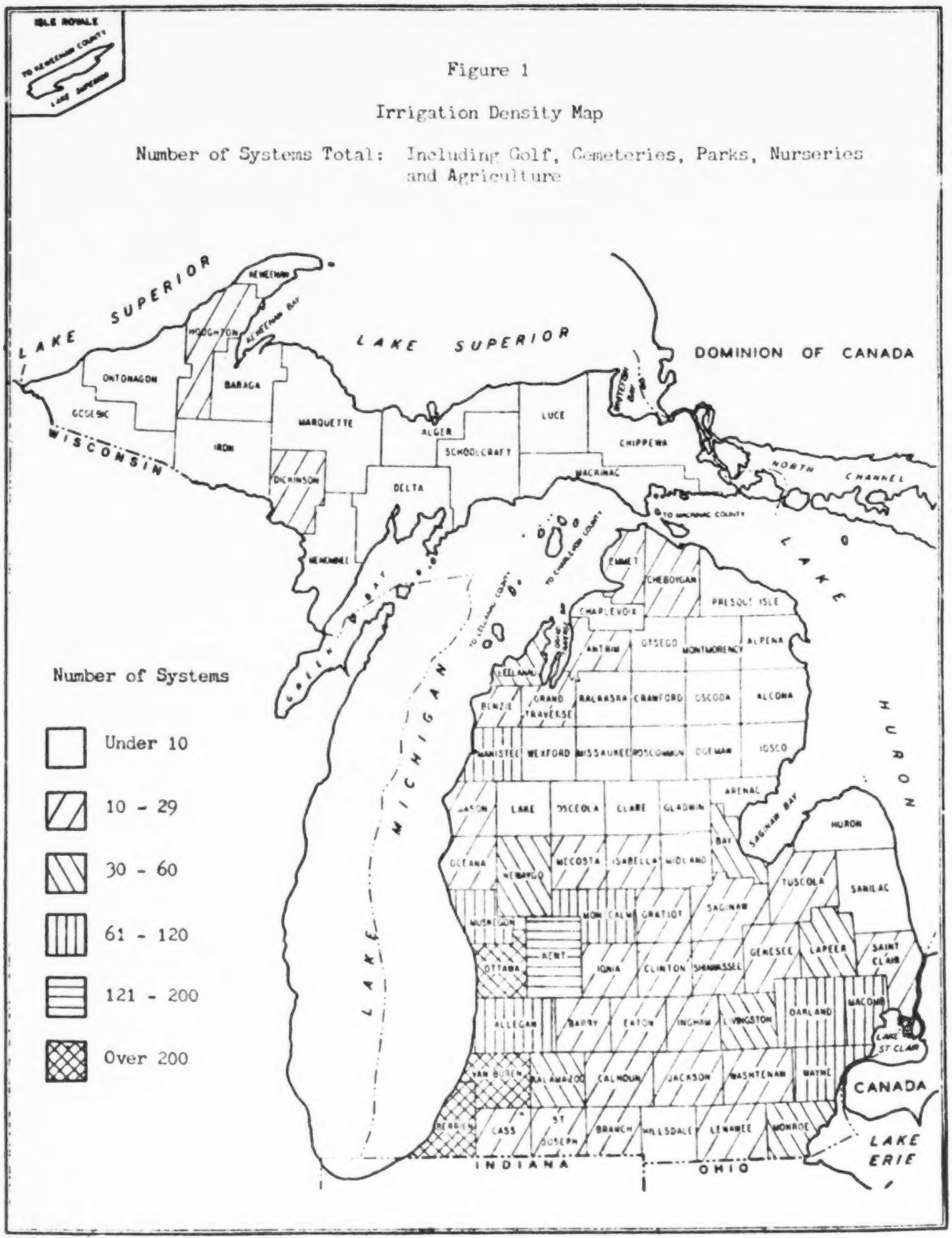


Figure 1

Irrigation Density Map

Number of Systems Total: Including Golf, Cemeteries, Parks, Nurseries and Agriculture

ISLE ROYALE
TO KEWEENAW COUNTY
LAKE SUPERIOR
LAKE SUPERIOR
LAKE SUPERIOR
DOMINION OF CANADA
WISCONSIN
NORTH CHANNEL
LAKE HURON
LAKE MICHIGAN
GREEN BAY
SAGINAW BAY
CANADA
LAKE ST CLAIR
LAKE ERIE
INDIANA
OHIO
TO MACKINAC COUNTY
TO CHARLEVOIX COUNTY
TO LEELANAU COUNTY
KEWEENAW
KEWEENAW BAY
HOUGHTON
ONTONAGON
GOGEBIC
BARAGA
IRON
MARQUETTE
DICKINSON
MENOMINEE
ALGER
SCHOOLCRAFT
DELTA
LUCE
CHIPPEWA
MACKINAC
EMMET
CHEBOYGAN
PRESQUE ISLE
CHARLEVOIX
ANTRIM
OTSEGO
MONTMORENCY
ALPENA
LEELANAU
BENZIE
GRAND TRAVERSE
KALKASKA
CRAWFORD
OSCODA
ALCONA
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
ARENAC
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
HURON
BAY
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
TUSCOLA
SANILAC
MUSKEGON
MONTCALM
GRATIOT
SAGINAW
KENT
OTTAWA
IONIA
CLINTON
SHIAWASSEE
GENESEE
LAPEER
SAINT CLAIR
ALLEGAN
BARRY
EATON
INGHAM
LIVINGSTON
OAKLAND
MACOMB
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
WAYNE
BERRIEN
CASS
ST JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE
Number of Systems
Under 10
10 - 29
30 - 60
61 - 120
121 - 200
Over 200

MICHIGAN WATER RESOURCES COMMISSION

Survey Data of 1958

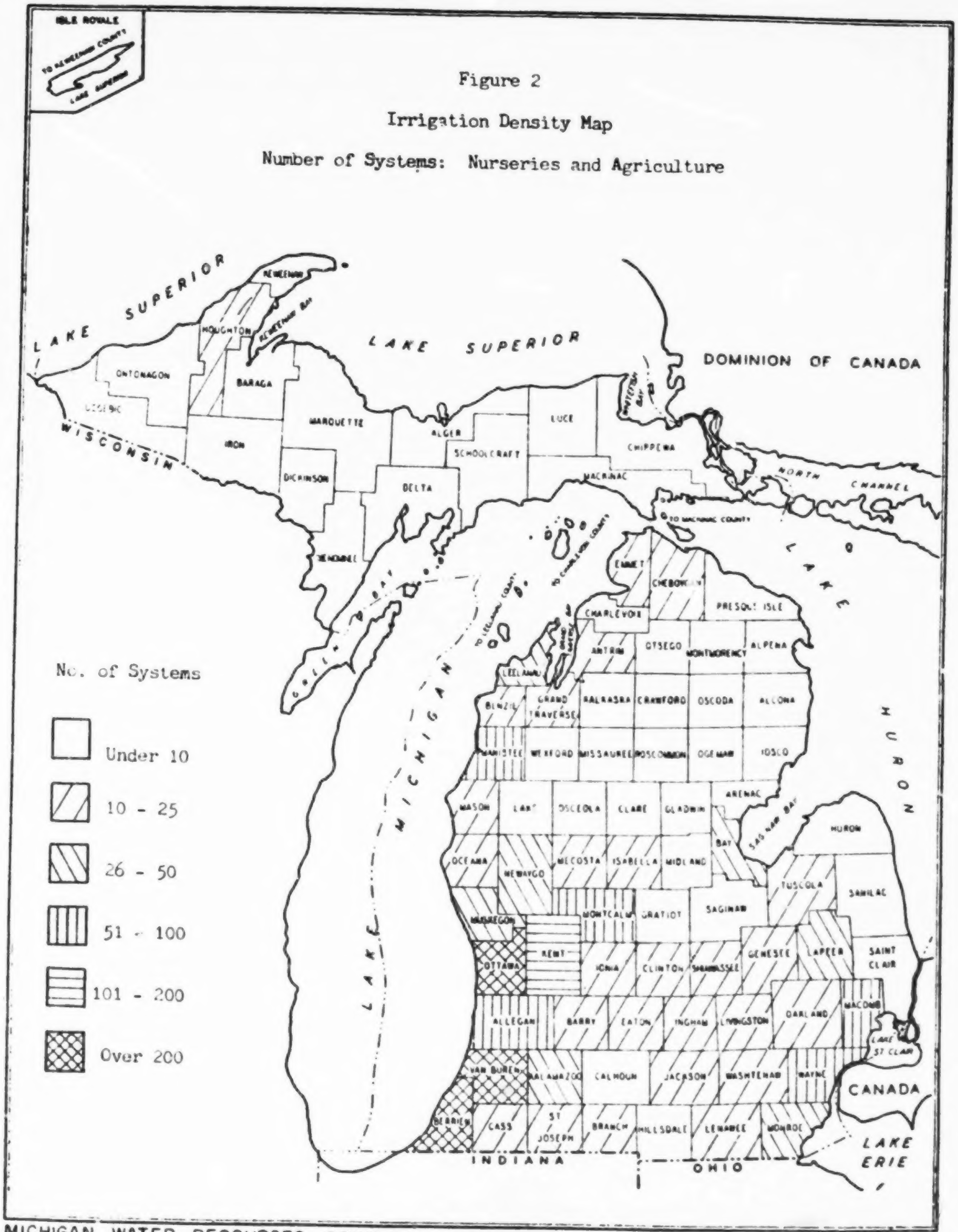


Figure 2

Irrigation Density Map

Number of Systems: Nurseries and Agriculture

ISLE ROYALE
TO KEWEENAW COUNTY
LAKE SUPERIOR
No. of Systems
Under 10
10 - 25
26 - 50
51 - 100
101 - 200
Over 200
LAKE SUPERIOR
LAKE SUPERIOR
DOMINION OF CANADA
WISCONSIN
NORTH CHANNEL
LAKE HURON
LAKE MICHIGAN
GREEN BAY
SAGINAW BAY
LAKE ST. CLAIR
CANADA
LAKE ERIE
INDIANA
OHIO
KEWEENAW
HOUGHTON
KEWEENAW BAY
ONTONAGON
GOGEBIC
BARAGA
IRON
MARQUETTE
DICKINSON
ALGER
SCHOOLCRAFT
LUCE
CHIPPEWA
DELTA
MENOMINEE
MACKINAC
TO MACKINAC COUNTY
TO LEELANAU COUNTY
TO CHARLEVOIX COUNTY
EMMET
CHEBOYGAN
PRESQUE ISLE
CHARLEVOIX
ANTRIM
OTSEGO
MONTMORENCY
ALPENA
LEELANAU
BENZIE
GRAND TRAVERSE
KALKASKA
CRAWFORD
OSCODA
ALCONA
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
ARENAC
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
BAY
HURON
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
TUSCOLA
SANILAC
MUSKEGON
MONTCALM
GRATIOT
SAGINAW
OTTAWA
KENT
IONIA
CLINTON
SHIAWASSEE
GENESEE
LAPEER
SAINT CLAIR
ALLEGAN
BARRY
EATON
INGHAM
LIVINGSTON
OAKLAND
MACOMB
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
WAYNE
BERRIEN
CASS
ST JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE

MICHIGAN WATER RESOURCES COMMISSION

Survey Data of 1958

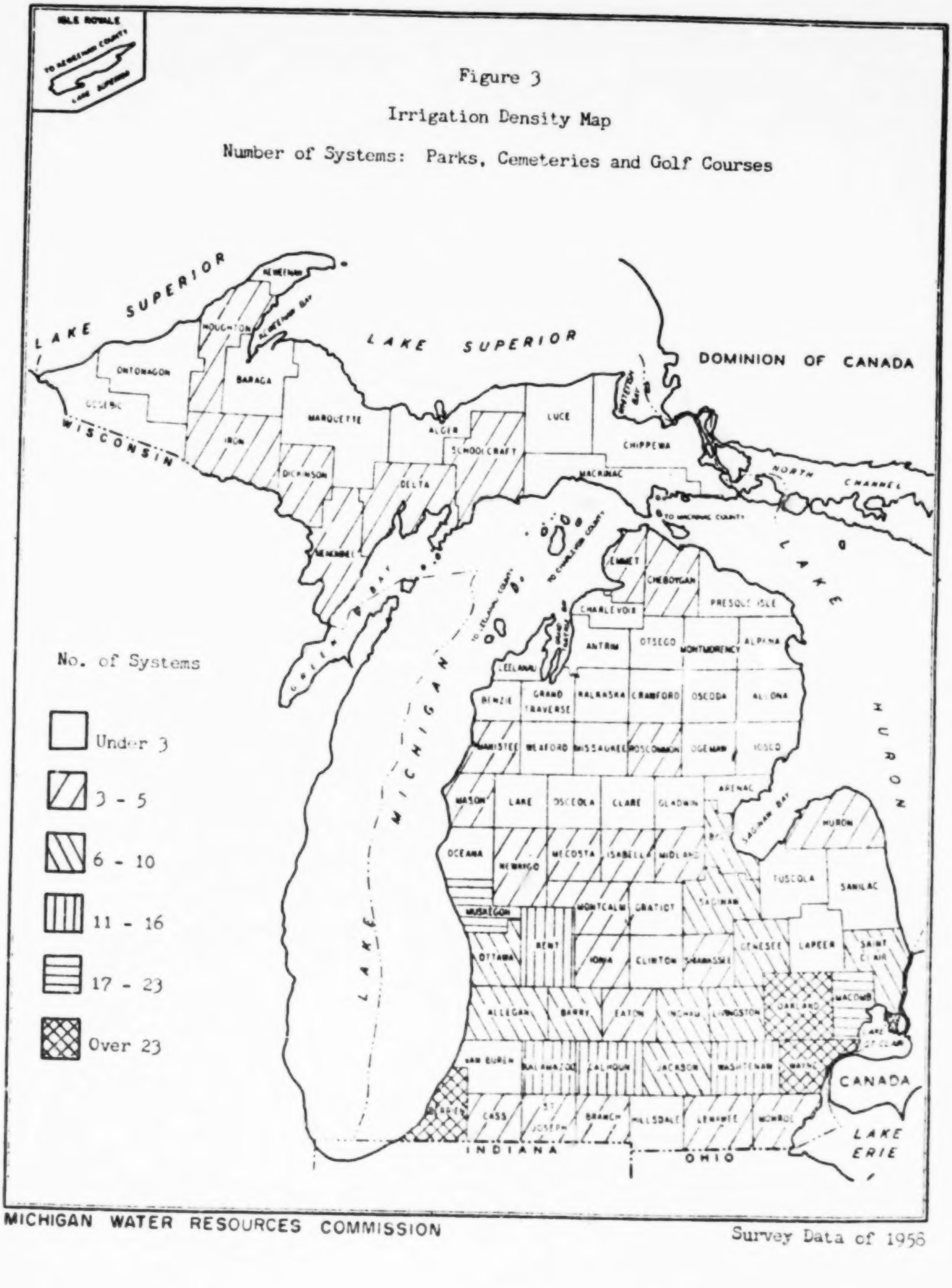


Figure 3

Irrigation Density Map

Number of Systems: Parks, Cemeteries and Golf Courses

ISLE ROYALE
TO KEWEENAW COUNTY
LAKE SUPERIOR
LAKE SUPERIOR
LAKE SUPERIOR
DOMINION OF CANADA
WISCONSIN
KEWEENAW
HOUGHTON
KEWEENAW BAY
ONTONAGON
BARAGA
GOGEBIC
IRON
MARQUETTE
DICKINSON
ALGER
SCHOOLCRAFT
LUCE
CHIPPEWA
DELTA
MENOMINEE
MACKINAC
NORTH CHANNEL
GREEN BAY
TO MACKINAC COUNTY
TO CHARLEVOIX COUNTY
TO LEELANAU COUNTY
LAKE HURON
EMMET
CHEBOYGAN
CHARLEVOIX
PRESQUE ISLE
ANTRIM
OTSEGO
MONTMORENCY
ALPENA
LEELANAU
BENZIE
GRAND TRAVERSE
KALKASKA
CRAWFORD
OSCODA
ALCONA
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
ARENAC
SAGINAW BAY
HURON
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
BAY
TUSCOLA
SANILAC
MUSKEGON
MONTCALM
GRATIOT
SAGINAW
LAKE MICHIGAN
OTTAWA
KENT
IONIA
CLINTON
SHIAWASSEE
GENESEE
LAPEER
SAINT CLAIR
ALLEGAN
BARRY
EATON
INGHAM
LIVINGSTON
OAKLAND
MACOMB
LAKE ST. CLAIR
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
WAYNE
CANADA
BERRIEN
CASS
ST. JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE
LAKE ERIE
INDIANA
OHIO
No. of Systems
Under 3
3 - 5
6 - 10
11 - 16
17 - 23
Over 23

MICHIGAN WATER RESOURCES COMMISSION

Survey Data of 1956

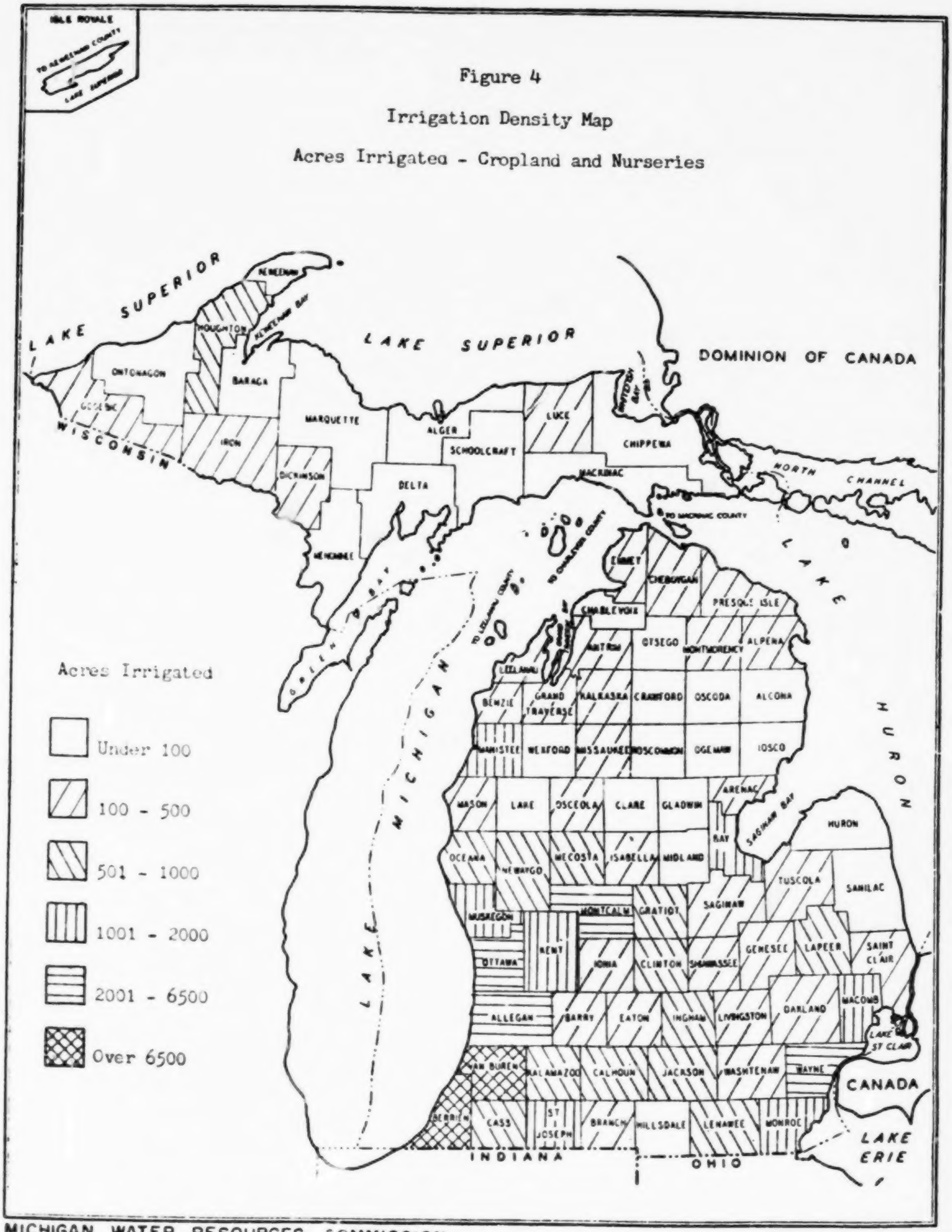


Figure 4

Irrigation Density Map

Acres Irrigated - Cropland and Nurseries

ISLE ROYALE
TO KEWEENAW COUNTY
LAKE SUPERIOR
LAKE SUPERIOR
LAKE SUPERIOR
DOMINION OF CANADA
NORTH CHANNEL
LAKE HURON
SAGINAW BAY
LAKE MICHIGAN
GREEN BAY
WISCONSIN
INDIANA
OHIO
CANADA
LAKE ST CLAIR
LAKE ERIE
KEWEENAW
KEWEENAW BAY
HOUGHTON
ONTONAGON
GOGEBIC
BARAGA
IRON
MARQUETTE
DICKINSON
MENOMINEE
DELTA
ALGER
SCHOOLCRAFT
LUCE
MACKINAC
CHIPPEWA
TO MACKINAC COUNTY
TO CHARLEVOIX COUNTY
TO LEELANAU COUNTY
EMMET
CHEBOYGAN
PRESQUE ISLE
CHARLEVOIX
ANTRIM
OTSEGO
MONTMORENCY
ALPENA
LEELANAU
BENZIE
GRAND TRAVERSE
KALKASKA
CRAWFORD
OSCODA
ALCONA
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
ARENAC
HURON
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
BAY
TUSCOLA
SANILAC
MUSKEGON
MONTCALM
GRATIOT
SAGINAW
OTTAWA
KENT
IONIA
CLINTON
SHIAWASSEE
GENESEE
LAPEER
SAINT CLAIR
ALLEGAN
BARRY
EATON
INGHAM
LIVINGSTON
OAKLAND
MACOMB
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
WAYNE
BERRIEN
CASS
ST JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE
Acres Irrigated
☐ Under 100
▨ 100 - 500
▧ 501 - 1000
▥ 1001 - 2000
▤ 2001 - 6500
▦ Over 6500

MICHIGAN WATER RESOURCES COMMISSION

Survey Data of 1958

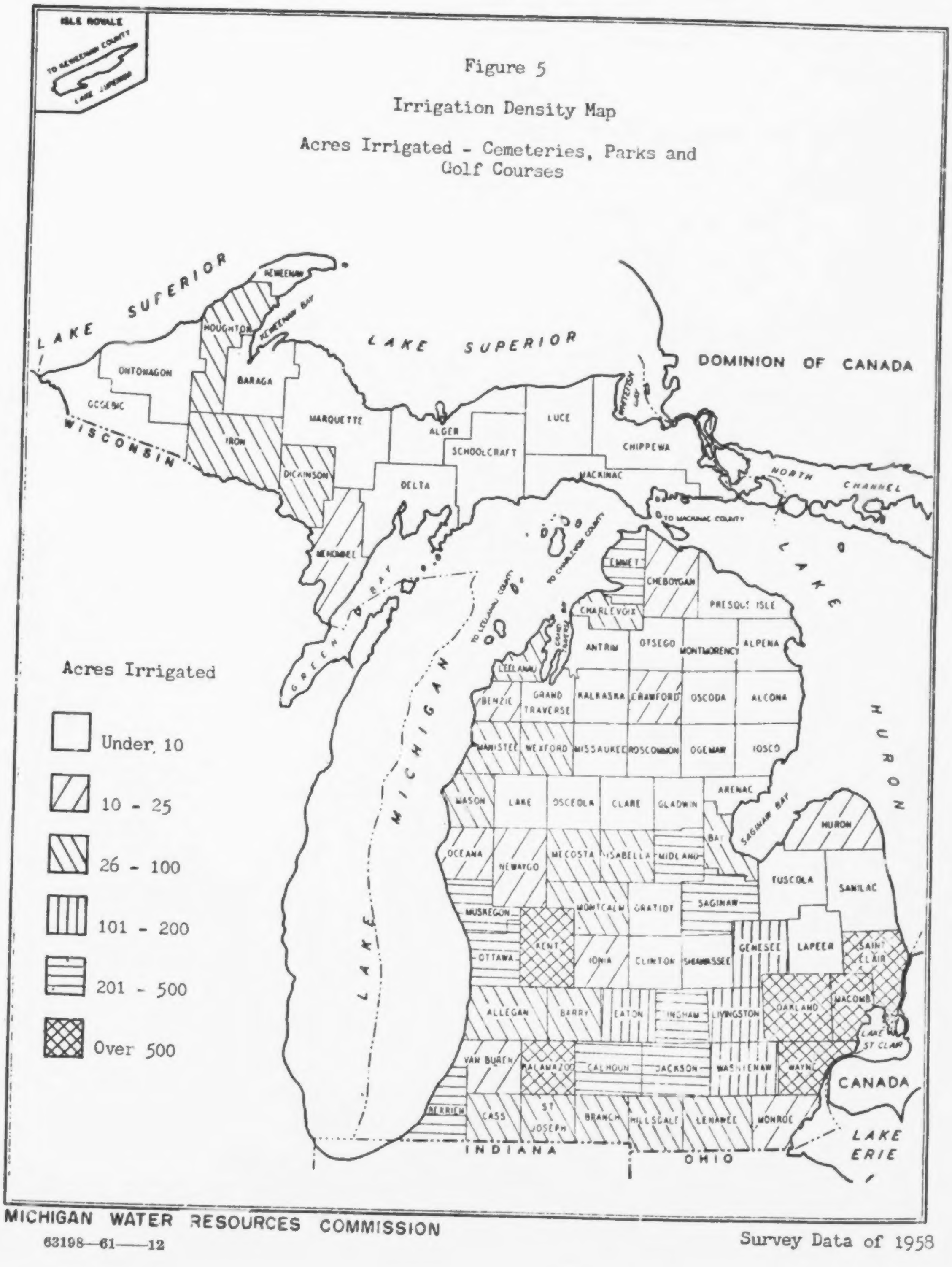


Figure 5

Irrigation Density Map

Acres Irrigated - Cemeteries, Parks and Golf Courses

ISLE ROYALE
TO KEWEENAW COUNTY
LAKE SUPERIOR
LAKE SUPERIOR
LAKE SUPERIOR
DOMINION OF CANADA
WISCONSIN
NORTH CHANNEL
TO MACKINAC COUNTY
LAKE HURON
SAGINAW BAY
GREEN BAY
LAKE MICHIGAN
TO LEELANAU COUNTY
TO CHARLEVOIX COUNTY
LAKE ST CLAIR
CANADA
LAKE ERIE
INDIANA
OHIO
KEWEENAW
HOUGHTON
KEWEENAW BAY
ONTONAGON
BARAGA
GOGEBIC
IRON
MARQUETTE
DICKINSON
ALGER
LUCE
SCHOOLCRAFT
CHIPPEWA
DELTA
MACKINAC
MENOMINEE
EMMET
CHEBOYGAN
CHARLEVOIX
PRESQUE ISLE
ANTRIM
OTSEGO
MONTMORENCY
ALPENA
LEELANAU
BENZIE
GRAND TRAVERSE
KALKASKA
CRAWFORD
OSCODA
ALCONA
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
ARENAC
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
BAY
HURON
TUSCOLA
SANILAC
MUSKEGON
MONTCALM
GRATIOT
SAGINAW
KENT
OTTAWA
IONIA
CLINTON
SHIAWASSEE
GENESEE
LAPEER
SAINT CLAIR
ALLEGAN
BARRY
EATON
INGHAM
LIVINGSTON
OAKLAND
MACOMB
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
WAYNE
BERRIEN
CASS
ST JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE
Acres Irrigated
Under 10
10 - 25
26 - 100
101 - 200
201 - 500
Over 500

MICHIGAN WATER RESOURCES COMMISSION

Survey Data of 1958

Figure 6

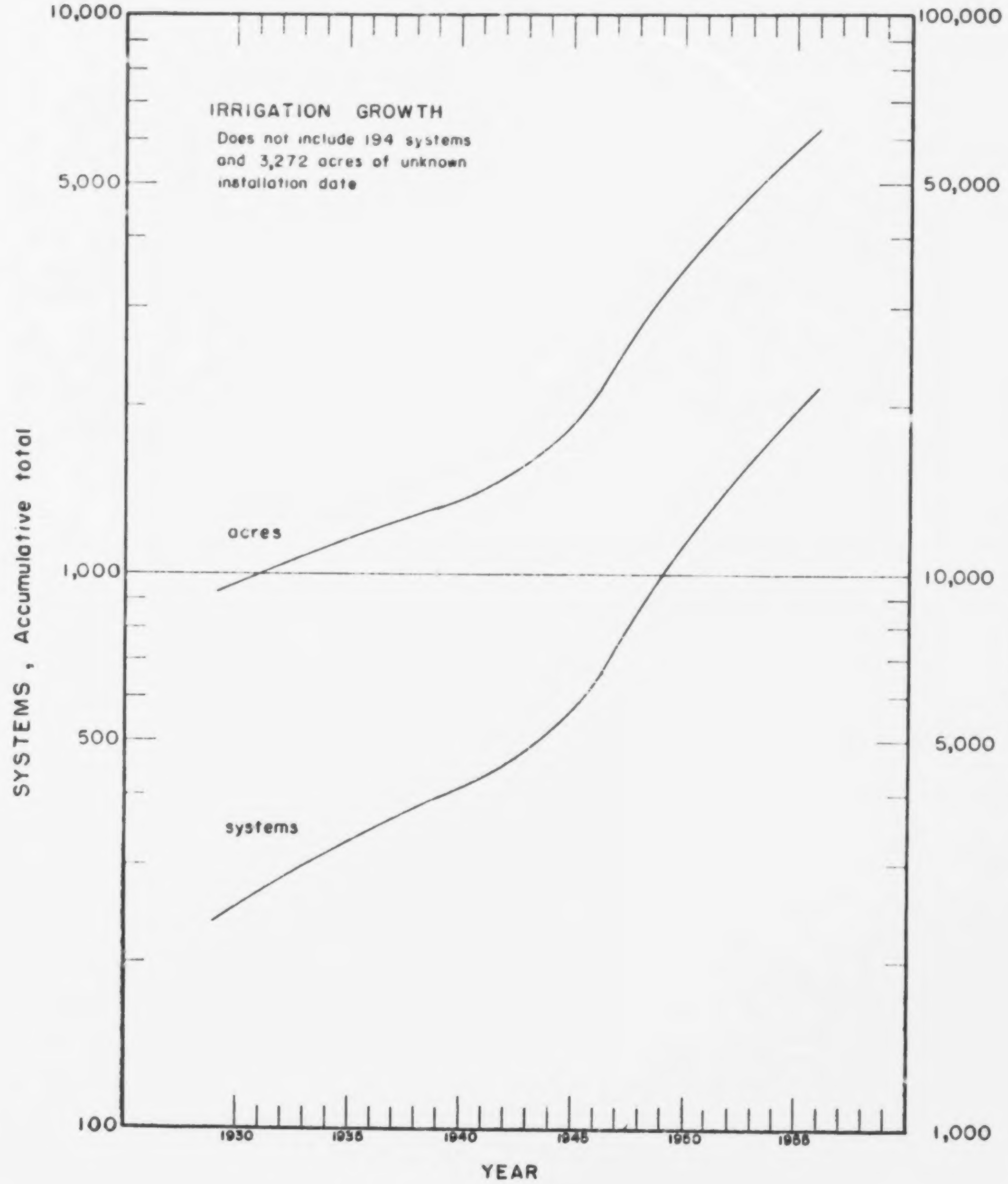

IRRIGATION GROWTH
Does not include 194 systems and 3,272 acres of unknown installation date
acres
systems
10,000
5,000
1,000
500
100
100,000
50,000
10,000
5,000
1,000
SYSTEMS , Accumulative total
ACRES, Accumulative total
1930
1935
1940
1945
1950
1955
YEAR

Figure 7

Sample Form

Black RIVER BASIN - IRRIGATION WATER USE SURVEY

I. Owner John F. Doe Date July 6, 1957

Address R.F.D #5, Holland, Mich.

Sec. 8 Twp. Johnson County Ottawa

II. Source Well & West Branch Maple Cr. Pumping rate 350 g.p.m.

Type of pump Gasoline centrifugal

If well, name of driller R. Roe

Address Holland, Michigan

Depth and Diameter of well 134', 6"

If surface supply, has pollution caused trouble? No When

Irrigated Soil Texture - Heavy, [✓ Medium], Light

III. System Designed for 50 Acres. Started irrigating 1951

Amount applied per application in inches 1

Average number of applications per year 4

Crops by acres, irrigated Strawberries 10, Tree Fruit 10,① Potatoes 10, Field Crops 10,② Truck Crops 10③

Has any shortage occurred? Yes When Summer 1954

How solved Built a reservoir on creek

IV. Future Use - Does owner plan to increase acreage Yes When 1960

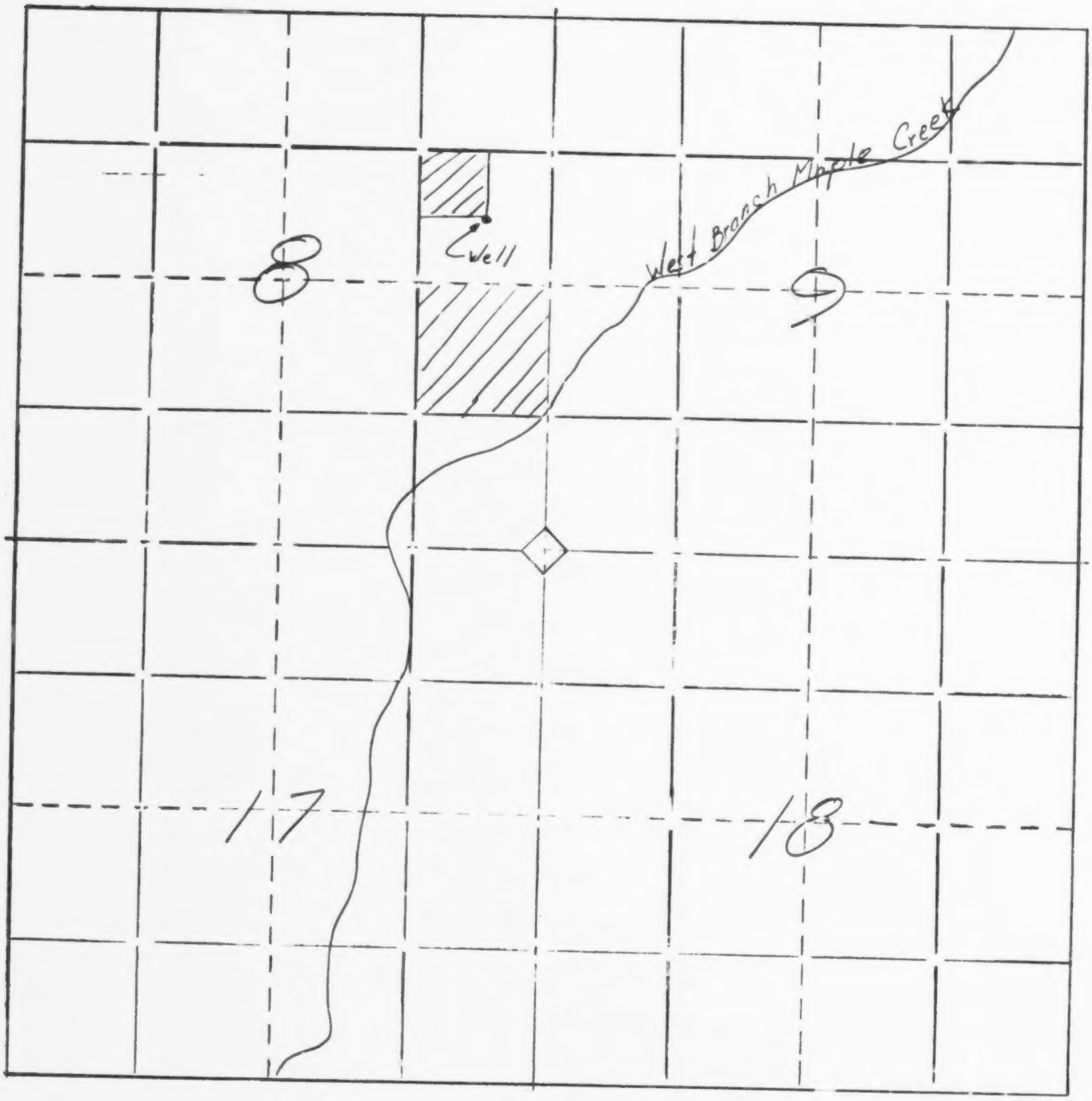
How many acres 20 Proposed source of water supply Same as above

V. Remarks - ① Apples & Pears
② Corn & Oats
③ Onions & Celery

SAMPLE FORM

IRRIGATION PLOT SITE LOCATION MAP

Sec. 8 Township Johnson County Ottawa


8
9
17
18
Well
West Branch Maple Creek

MINNESOTA

STATE OF MINNESOTA,
EXECUTIVE OFFICE,
St. Paul, September 4, 1959.

Hon. ROBERT S. KERR,
Senator from Oklahoma,
Senate Office Building,
Washington, D.C.

DEAR SENATOR KERR: Thank you for this opportunity to present an analysis of Minnesota's water and resource picture with its particular emphasis on our present and future problems, and our recommendations as to a proper course of action in meeting these problems. The material presented here has been prepared by our Water Resources Board. It provides as accurate and up-to-date summary as is possible.

I hope the Minnesota statement will be helpful, and I hope you will call on us again if we can provide additional information.

Sincerely yours,

ORVILLE L. FREEMAN, *Governor.*

A STATEMENT OF WATER PROBLEMS IN MINNESOTA PREPARED FOR THE SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES AT THE REQUEST OF HON. ROBERT S. KERR, SENATOR FROM OKLAHOMA

(Presented by the Honorable Orville L. Freeman, Governor of Minnesota)

The following is a brief set of conclusions prepared on the recommendations of the Minnesota Water Resources Board and based on the study outline submitted by the National Water Resources Senate Committee. The main body of the memorandum will give additional details and reasons for these conclusions.

CONCLUSIONS

1. There is no overall water shortage in the State. Presently, there is no need to choose between various consumptive uses.

2. Problems are presently those of transportation and storage of water. To assist localities in this respect, the following legislation is recommended.

(*a*) Legislation that permits interwatershed diversion of surplus water. Under our present system of riparian water law, this may not be done. However, the legislature has created an exception for purposes of taconite development. It is suggested that this diversion be permitted for all beneficial uses.

(*b*) Legislation that permits storage of excess flow for flood waters. This is also in doubt under our riparian law. Accompanying this legislation should be safeguards that would insure against over consumption. These should be in terms of required optimum or minimum flow regulations.

(*c*) Legislation that would permit use of excess floodwaters on nonriparian land. Under certain court decisions, the term "riparian land" has been given very narrow construction. Legislation of this type would permit broader beneficial use of excess water.

3. The biggest problem in formulating State policy is the lack of adequate analysis of existing information. Meaningful conclusions on the location and amount of our water supply could be made from existing records. Little work has been done on estimating present and future water demands. However, reasonably accurate estimates could be made through a survey of agencies and units of government.

4. There is no need to change our present system of water law from that of riparian to an appro-

priation system. However, as mentioned above, certain important improvements can be made within the system.

5. We have serious flood problems. The number of projects instituted under Federal agencies has increased in the past 10 years. Reduction of damages occasioned by these projects is encouraging. The following legislative enactments would help alleviate the flood damage problem.

(*a*) Adoption of flood plain zoning.

(*b*) A Federal requirement as proposed in the Flood Insurance Act requiring adoption of flood plain zoning before a project could receive Federal funds.

(*c*) Need for a State agency representative of all water interests to negotiate with Federal agencies.

(d) A State work plan party to assist local units in planning water projects and in establishing flood plain zones.

ADDITIONAL RESEARCH NEEDED

1. Development of materials and processes that would reduce evaporation and seepage from small reservoirs and farm ponds.

2. Additional research and publication of evaporation and transportation in various watersheds of the States.

3. Research on inexpensive treatment of small quantities of polluted material, both municipal and industrial. Research on disposal and treatment of new and unusual pollution including detergents, various chemicals, and radioactive substances.

4. Development and design of economically feasible system of recirculation and reuse of water for small- and medium-sized municipalities.

5. Additional research on safe methods of ground-water recharge.

6. Economical means of removing excess minerals from saline ground water.

7. Economic studies of the impact and effect of various price changes on water consumers within the State.

8. Studies need to be made and values placed on the use of water for nonconsumptive purposes. The effect of a diminishing quantity and quality of water on recreational uses should also be studied.

SUMMARY OF WATER RESOURCES AVAILABLE

As has been expressed many times, the amount of available water is the product of several factors. In defining available water resources, it is necessary to consider three intrarelated limitations: the physical, the economic, and the legal. Each of these factors may limit the available water supply. The limits of each of the factors may be dependent on the others and may be changed by development in the other two.

The physical limitations determine the limits of physical possibilities in terms of water sources, supplies, and uses. This, of course, may be enlarged by the discovery of new technical improvements. Water may be physically present but it is of little benefit if the cost of obtaining it is economically unfeasible for contemplated uses. Economic limitations change with technical improvements and with changing consumer preferences for goods and services. Finally, water may be physically available and its use may be economically feasible, but if our laws prohibit potential consumers from using this water they may not consider it an available supply.

If the purpose of estimating the water supply is to make increased use of available water, certain action may be necessary on the part of the public, thus somewhere at some time a supply that appears to be limited by pure physical, economic or legal conditions may actually be subject to a political limitation resulting from the public's inability to arrive at a common or prevailing decision.

This introduction describes the framework within which available water resources must be calculated. I believe it is necessary to dispel the idea that the physical factor is the only limitation on our available water supply. Considering the natural resources of the State, it may be the least important factor at this time. While the introduction of other factors is realistic, it complicates the task of estimating our available resources.

In many respects, Minnesota is in an enviable position in regard to water supply. With very minor exceptions, all of our surface water originates within the State. Thus we do not face the possibility of having our supply reduced by increased consumption in other States.

Flow measurements of Minnesota streams indicate the following runoff to other States, at or near the Minnesota boundary.

River	Cubic feet per second		
	Maximum	Average	Minimum
Rock	....	374	....
Des Moines	8,360	311	0
Red	95,600	2,735	1
Mississippi	196,000	27,730	3,300
St. Louis	13,200	2,075	200
Rainy	71,600	13,270	2,200

It is apparent that a great deal of water is leaving the State. This is not to imply that it should all be consumed or that it is necessarily wasted. Many of these waters are used for nonconsumptive purposes such as navigation, recreation, propagation of fish and wildlife and for waste removal. These uses are important and must necessarily continue. The optimum or minimum flows necessary for these purposes should be determined for each major stream in the State. These calculations plus our existing streamflow records would give some indication of the amount and location of excess waters available for expanded consumption.

The vast fluctuation between minimum, average and maximum flows indicate that we are not managing our watersheds. Minimum flow figures indicate that many of our major rivers cease to flow during prolonged droughts. These streams cannot be considered as a reliable water supply. Two examples of the use of man-made structures to regulate flow are the headwater reservoirs on the Mississippi and the Orwell Dam on the Ottertail Dam. Construction of additional structures in the headwater of our major rivers are needed for flood control and water management.

In addition to our network of rivers and streams, Minnesota has been abundantly blessed with lakes. Our topography is such that there are thousands of depressions to catch and hold the surface runoff. Our rainfall ranges from 32 inches in the southeastern part of the State to 20 inches in the northwest. Our evaporation rate is estimated from 20 inches to 39 inches per year. This ratio is very favorable when compared with many of the States south and west of us. Because of these favorable conditions, Minnesota has the largest area of surface water of any State in the Nation.

Like our rivers, the lakes are used for a variety of purposes. The big problem is to develop plans that will permit the greatest beneficial use of these waters for the greatest number of people. In their natural state, these lakes control runoff by reducing floods and by supplying water to streams during times of deficient moisture. By installing controlled release structures in their outlets, man can further manage the water. It should be noted that if the lakes are to be used for multiple purposes, compromises will be necessary. A lake may be used for flood control, water storage and recreation. But the maximum potential of any of these uses may not be achieved if consideration is given to the others.

In discussing ground water supplies, the State should be divided into four areas. Ground water supplies are considered excellent in the east central and southeastern parts of the State. This area has our highest rainfall and a low evaporation rate. It also has good infiltration and good storage in the sandstone and limestone aquifers. The entire western part of the State, together with the north central part, constitutes an area of ground water shortage. This area has low precipitation and high evaporation and very poor ground water recharge and storage. The northeastern corner of the State has a small groundwater supply because of poor infiltration and ground-water storage. The remaining part of the State described as the central lakes area has large aquifers capable of yielding good supplies. These are located where the glacial drifts are predominantly sandy.

Surface and ground water should be considered together in evaluating the adequacy of water supplies. When this is done it appears that the most serious problem is in the western part of the State. This is particularly true of the southwestern corner and the Red River Valley. As mentioned above, the ground water supplies in those parts of the State are limited. In addition, much of the ground water is so highly mineralized that it cannot be consumed without extensive treatment. The streams in these areas have ceased to flow during prolonged drouth. There are very few lakes or natural reservoir sites. A number of municipalities have experienced water shortages. However, extensive surveys have discovered additional ground water to supply present needs. Additional surveys plus development of surface water storage appears to be the most likely solution in the near future. Physical and economic limitations have and will continue to prevent industries which require large amounts of water from developing in many locations in this area. In the future, the solution might depend on the comparative cost of transporting water from increasing distances or treating and recirculating the limited supply.

When irrigated agriculture becomes profitable in Minnesota, farmers in these areas will have a difficult time securing an adequate supply. Extensive use of small dams and farm ponds on the upper watershed may solve the water irrigation problem but this will reduce runoff to streams and further complicate matters for other users, particularly nonconsumptive users.

Major population and industrial growth of the State is expected in the Twin City metropolitan and southeastern part of the State. Fortunately, this area is well endowed with water resources. The ground water is capable of producing large supplies for industrial purposes. Much of the area is adjacent to sizable streams including the Minnesota and Mississippi Rivers. Major problems in this area are to prevent waste and exploitation of the ground water and to avoid excessive pollution of both surface and underground water.

The north central and northeastern areas of the State appear to have adequate surface water to offset a deficient ground water supply. Several of the larger cities of the northern part of the State use surface water for municipal purposes. Much of the area is sparsely settled and the demand for water is not great. The taconite industry, however, needs large supplies of water. A great deal of survey work has been done to locate adequate supplies. Adequacy of water supply will be an important factor in locating plants but the lack of water should not prevent the industry from expanding. It may be necessary to consume a substantial part of certain lakes or streams but the economic return will be very substantial. The central lakes area have sizable supplies of surface and underground water. From all reports these are adequate for present demands. This should also remain true for the foreseeable future.

WATER DEMAND

There has been a great deal written about this subject in general but very few detailed estimations have been made. The only publications available for Minnesota are those of the U.S. Geological Survey. These publications give estimated demands for various types of consumers. However, these figures are for the entire State. What is needed is a breakdown of these figures for various watersheds within the State. The demand figures should be projected by considering expected expansion in population, industry and by other potential consumers.

1955 estimates of withdrawals in Minnesota are as follows (figures are in million gallons per day):

Purpose	Ground	Surface	Total
Public supplies	50	94	144
Rural	72	21	93
Irrigation	2	7	9
Self-supplied industrial	190	1,400	1,590
Total (excluding waterpower)	323	1,522	1,836
Waterpower			32,000

The accuracy of these estimations may be questioned. In 1950 it was estimated that self-supplied industry used surface water at the rate of 10 million gallons per day. In 1955 this estimation was changed to 1,400 million gallons per day. This vast change was made because of the establishment of the taconite industry. However, it was apparent that if the estimate for this industry is substantially inaccurate the magnitude of the entire State totals would be changed.

The figures listed above are for withdrawals rather than consumption. More than 90 percent of the water withdrawn for municipal and industrial purposes is returned. If the quality of the water returned is adequate, it may be reused. Also, much of the water may be used for more than one process before being returned. Thus, it is difficult to correlate figures on withdrawals, consumption, and use. Irrigation uses, unlike municipal and industrial uses, consume about two-thirds of the water withdrawn. Any widespread increase in irrigated agriculture would have a substantial effect on water consumption.

FLOOD PROBLEMS

There is quite a number of streams and rivers within the State that present periodic flood problems. Major flood damage occurs where man has concentrated economic development within flood plains. Our rapidly increasing population will cause this practice to be increased. Flood plain zoning is necessary to prevent increasing flood damage.

Estimates by the U.S. Corps of Engineers indicate that during the 10-year period from 1943 to 1952, Minnesota suffered $60 million in flood damage. Of this amount, $25 million was in the Red River Basin and $35 million in the Mississippi Basin. Greatest damages were on the main streams of the Mississippi ($15,123,000), the Red River ($8,410,000), the Minnesota ($10,917,000), the Mustinka ($2,516,000), Red Lake, and Clear Water Rivers ($2,799,000), Roseau ($3,292,000), Root ($2,290,000), and South Forks of the Crow ($2,326,000).

Flood control projects on the main streams are under the jurisdiction of the U.S. Corps of Engineers. Smaller upstream projects may be instituted under the U.S. Soil Conservation Service. There are three general methods of controlling floods. Reservoirs may be contructed to hold peak flows and release the waters at a safe rate. Flood capacity may be increased by enlarging and straightening the stream. Local protection works (dikes and floodwalls) may be constructed to protect a certain area. All three of these methods have been used in Minnesota. However, it is generally agreed that large reservoir sites are not available to control major floods on large rivers.

Certain information on completed flood-controlled projects is listed below:

Name	Year completed	Damages prevented to date	Initial Federal cost
Orwell Reservoir, Ottertail River	1953	$601,400	$1,918,000
Ottertail River	1955		178,000
Wild Rice	1952	20,500	419,000
Marsh River	1955		
Sand Hill River	1958		568,000
Mustinka River	1958	62,000	467,000
Lake Traverse, Bois De Sioux	1948	754,900	[1] 1,332,000
Red Lake River and Clearwater River	1956	1,227,500	2,876,500
Mississippi River near Aitkin	1957	650,800	1,672,535

[1] Maintenance, $222,600.

The useful life of these projects is usually considered to be at least 50 years. In the short time that these projects have been in existence they have prevented rather substantial damages.

Flood-prevention projects now underway include Ruffy Brook and Lost River, Lac Qui Parle, Mississippi River at St. Paul and South St. Paul, and the Minnesota River at Mankato. Total Federal cost of these projects is estimated at $10,585,000. Local contribution will be approximately $1,636,000.

In addition to the major projects mentioned above, the corps has a number of small flood control, and snagging and clearing projects. In some instances these projects have been delayed and even discontinued when it was found that provisions for local cooperation could not be met. An examination of the possibility of giving a State agency the authority to insure local cooperation should be made. Provision would have to be made to ascertain the feelings of local property owners before the State agency and corps agreed on a project. A system similar is presently used in North Dakota. For small projects this method would be superior to establishing a special watershed district.

The U.S. Soil Conservation Service has completed a small, upstream flood-control project on the East Willow Creek area near Preston, Minn. This area received heavy rains during the late spring of this year. While an economic analysis of the effectiveness of this project is not available, newspaper reports credit the project with major reduction in damages within the watershed.

Within the last 10 years there has been a noticeable increase in Federal flood-control projects within the State. If this activity can be sustained, much of the flood damage reported above will be substantially reduced. The State should assist local areas by offering professional planning and by assisting the local people in their negotiation with the Federal agencies.

WATER POLLUTION

It is difficult to objectively measure the amount of pollution in the State. Certainly this is a factor which must be considered in estimated water supplies. Most reports indicate that the concentration is not as great as in more populated and industrial areas. Out standards will have to remain considerably above these areas in order to maintain our reputation as a recreation area. The legislative interim commission on water pollution made several recommendations. The most basic of these concerned the adoption of standards of pollution. These should vary depending upon the general use of the water.

A recent report indicated that all cities in the State, having a population of over 3,000 which have sanitary sewers, have progressed at least to the point of planning for sewage treatment. From 1950 to 1957, 117 communities had constructed or improved disposal plants. Whether this construction is keeping pace with the increasing amount of pollution is debatable . The State enforcement agencies know which municipalities are not adequately treating their sewage. Generally, industrial sources are not as well known.

In order to improve the present situation, the following general steps are suggested:

1. Adoption of stronger pollution legislation together with vigorous enforcement at the State level.
2. Establishing of adequate pollution standards.
3. Installation of adequate sampling stations to make certain the established standards are being complied with.
4. Increased financial aid to municipalities in terms of grants and loans from both State and Federal Governments.

SURFACE DRAINAGE

The most highly debated and controversial water problem in the State involves surface water drainage. The necessary result of agricultural drainage is the reduction of wildlife habitat. In considering this conflict, a few basic facts should be considered.

Well planned drainage of good agricultural land has been of great benefit to landowners and to the economy of the State. A landowner should have the right to dispose of his surplus water. However, this should be done in a reasonable manner and with consideration to its effect on other landowners and the general public. Benefits derived accrue to the landowners and should be financed by special assessments. Subsidation from general revenue may bring marginal projects into existence.

PRESENT DRAINAGE LAWS HAVE SEVERAL SHORTCOMINGS

They allow projects to be constructed without adequate regard to the effect or interest other than those represented by the petitioners. The petitioners suggest the route of the drainage project. Inadequate consideration is given to alternative plans. A plan that is most economical for the petitioners may not be the best alternative when other interests are considered.

The engineer is appointed by the hearing body and is supposedly to give them impartial reports. However, his reimbursement depends on the construction of the project, so in reality he becomes the advocate of the petitioners. Projects are established without any overall plan for the watershed. Only lip service is paid to the requirement that the outlet must be adequate. This has the effect of transferring drainage problems from the upper to the lower part of a watershed. Inadequate provision is made for maintenance of projects;

The answer to the drainage-wildlife controversy plus many other water problems lies in total land and water management. This should be done on a watershed basis and at the local level. General policy, assistance, and in some cases regulation, will have to come from the State level. Minnesota has a start on this program through its watershed legislation. The Federal Government is assisting through its agencies and programs. The speed with which this program is accomplished will depend on public opinion. This will be shaped by the severity of emerging problems and conflicts.

MISSISSIPPI

State of Mississippi,
Board of Water Commissioners,
Jackson, Miss., December 9, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: At the request of Gov. J. P. Coleman, the Mississippi Board of Water Commissioners has prepared the attached statement on the water resources of Mississippi.

We appreciate this opportunity to express the views of our people on this important subject. You can expect our cooperation at any time that it is requested by you or your committee.

Respectfully submitted.

Sam A. Thompson.

Statement to U.S. Senate Select Committee on National Water Resources

(By Mississippi Board of Water Commissioners)

Governor Coleman directed the board of water commissioners to present Mississippi's views.

The Mississippi Board of Water commissioners is the State agency that administers the water rights laws of Mississippi.

In order that the committee might know the intense interest of our State in the proper utilization of our water resources, we would like to give you a brief background of the activities leading to the passage of State water rights legislation.

Mississippi is primarily an agricultural State. Its economy is based upon agricultural production and the processing and distribution of that production.

Our State is richly endowed with a fertile soil, favorable climatic conditions which provide a long growing season for a variety of crops, and a rainfall pattern ranging from a 20-year average of 46 inches in the northern part of the State to 65 inches in the southern part of the State. Unfortunately, this precipitation is not evenly distributed throughout the year and provides periods of excess, or flood, and periods of drought.

Out of this problem of having too much water at one time and too little at another, we recognized the necessity of taking some State action that would permit us to use our water resources and to control them.

We did not really become fully aware of this problem until 1951 when we began to study our water use problems in relation to our water resources. From 1951 to 1956 we had severe droughts during the growing seasons, and, since Mississippi is primarily an agricultural State, this drought affected our entire economy. It was organizations and business interests that made the first survey of our needs. They recommended to the Mississippi Legislature that the State provide funds and take up the study, based on findings in fact to, and provide the necessary legislation to cope with these problems.

When the Water Facilities Act was extended in 1954 to cover our section of the country, our farmers endeavored to obtain loans from the Government for irrigation installations. We found that the U.S. Government would not make these loans without a secure water right under State law. This speeded up our study of the problem and resulted in comprehensive water rights legislation adopting the appropriation theory, but retaining the riparian doctrine as applied to domestic use of surface water.

This legislation was passed April 6, 1956. The program has just completed its third year of operation. We have some 1,500 water rights that have been granted by our board.

We would like to give two illustrations of the effective application of our law in the development and use of water resources in the State:

First, the Sixteenth Section Development

Corp. was formed and leased a section of school land in Hinds County, 7 miles west of Pearl River. Bonds were sold and a 5,000-acre-foot lake was constructed. Water from this lake was contracted for a 20-year period to a power company for cooling purposes. The returns will pay the construction costs amortized over this period, the maintenance of the facilities, and provide a return to the schools of Hinds County of over 10 times the former annual income. In addition to this use, additional plant sites can be located and additional income derived from industrial use of this water. A 100-acre recreational ground area is provided and recreational use of this water is available on an organized basis. This installation is 7 miles from its source of supply and could not have been constructed under the riparian doctrine as it prevailed prior to the passage of our law.

Second, the Pearl River Valley Water Supply District was created by State law. It has completed a survey and is buying the land to construct a dam on Pearl River and impound water creating a 34,000-acre reservoir of approximately 320,000 acre-feet of water. Bonds will be sold to finance this project. There is not one penny of Federal money in this or the first example of water. resource development under the State law. The sale and use of water from these installations will pay for their cost and provide a continuing source of income and employment in our State.

We feel that Mississippi is on the right track to handle its surface water problems in the future. Proper advanced planning can eliminate many problems. Comprehensive soil and water use studies are underway in cooperation with Federal and State agencies and organizations, and will be continued and expanded until every river basin of the State has been studied. These studies can serve as the basis for water management plans that begin where the rainfall strikes the ground and continues through adequate outlets to the Gulf of Mexico. These plans can provide for proper land use and soil conservation practices that assist in overall water and soil management. Reservoir sites can be selected and used for multipurpose dams when needed for additional water supplies.

The board feels that Federal financial and technical assistance should be continued and increased to meet accelerating needs under Public Law 566 and other programs that carry out water management plans.

The director of sanitary engineering of the Mississippi Board of Health feels that Public Law 660, 84th Congress, amending the Pollution Control Act, is doing an adequate job without any revisions. Since July 1956, more than $16 million have been spent in Mississippi for public sewage works. With a continued educational program, and possibly some State regulatory legislation, municipal sewage pollution of streams can be brought within allowable limits.

The Mississippi Game and Fish Commission submitted a separate statement at Alexandria, La., that gave views on recreational use and stream industrial pollution control that falls under their jurisdiction.

Mississippi's Water Rights Act of 1956 does not apply to ground water rights or usage. Local problems are being reported from several areas of the State, but the board of water commissioners does not have adequate data at this time on which to base recommendations for ground water legislation. Additional State funds have been requested to be used to match Federal funds to finance an expanded study of ground water in cooperation with the U.S. Geological Survey.

The following pages will give, in more detail, the summary of water resources and activities in Mississippi.

WATER RESOURCES OF MISSISSIPPI

I. STATEMENT OF EXISTING SITUATION AND PRESENT TRENDS

A. Summary of water resources available

1. Rainfall pattern ranges from a 20-year average of 46 inches per year in the northern part of the State to 65 inches in the southern part. Jackson, near the geographical center of the State, has a long-time average of 54 inches.

2. Runoff into surface streams will average about 21 inches per year. The relation between rainfall and surface runoff is not constant, varying from basin to basin, and even varying within the basin from storm to storm and from year to year. Magnitude and intensity of the storms nature of the soil, and degree of soil moisture, and presence of reservoirs in the drainage basins are a few of the

many factors affecting the rainfall-surface runoff relationship.

(*a*) *Streams.*—The defined surface water resources of Mississippi consists of rivers, streams, and lakes, together with certain artificial reservoirs established at strategic locations. The rivers flow mainly into the Mississippi River or Gulf of Mexico, and they perform a primary function of drainage for excess rainfall. Among the principal rivers are the Tombigbee, the Yazoo, the Pascagoula, the Pearl, and the Big Black. The only major streams of concern to neighboring States, other than the Mississippi River, are the Tombigbee and the Pearl.

(*b*) *Stream Reservoirs.*—The principal reservoirs in the State are those on the upper tributaries of the Yazoo River. Arkabutla Reservoir on Coldwater River, Sardis Reservoir on Tallahatchie River, Enid Reservoir on Yocona River, and Grenada Reservoir on Yalobusha River comprise the reservoirs of the Yazoo River system.

The elimination of major floods through the storage of excess water in the winter and spring provides stable flows in the summer as a supply for agricultural irrigation.

These reservoirs, although their principal purpose is flood control for the alluvial plain, furnish some of the finest recreational opportunities in the South. Pickwick Lake on the Tennessee River in the extreme northeast of the State, though primarily an electric power and flood-control development, furnishes exceptional recreational opportunities.

Smaller reservoirs, used for recreational opportunities are scattered throughout the State. Bogue Homo Lake in Jones County, Lake Tangipahoa in Pike County, and Choctaw Lake in Winston County are among the more popular.

(*c*) *Natural Lakes.*—Natural lakes are located for the most part in old meander belts adjacent to the Mississippi River. Lake Beulah, Lake Bolivar, Lake Washington, and Eagle Lake are among the largest of these lakes. Until recent years, these lakes have been of economic importance mainly for recreational and commercial fishing purposes. During the recent drought years the entire supplies of Lakes Beulah and Bolivar were used for irrigation. There has also been some irrigation development in Lake Washington.

(*d*) *Ground Water.*—Mississippi, with the exception of a very small area in the northeastern corner, lies entirely within the Gulf Coastal Plain, and is underlain by a series of sedimentary deposits. The foundation of the State consists of dense rocks like granite, known as basement rocks. These rocks do not come to the surface in Mississippi, but are found in the heart of the Piedmont Plateau which extends through eastern Tennessee and into the Birmingham, Ala., area. In Mississippi the basement rocks are buried deeply beneath a covering of stratified rocks, ranging in thickness from several hundred feet to many thousand feet. These stratified rocks are consolidated sedimentary formations like limestone, sandstone, and shale, and unconsolidated sediments such as gravel, sand and clay. The northern half of Mississippi occupies a portion of a large structural trough known as the Mississippi Valley embayment. This embayment extends up the Mississippi River as far as southern Illinois, and the series of deposits filling it form one of the most important ground-water regions in the United States.

(*e*) *Water Quality.*—There is a great need for ground and surface water information on water quality. Generally, water of acceptable quality is available in any part of the State.

B. Statement on withdrawal and use of water

1. Mississippi adopted the appropriation theory for its surface-water resources. Water users, other than for domestic purposes, must secure permits from the board of water commissioners. The 1956 act does not affect ground-water rights or usage.

(*a*) The surface-water uses, as filed in the office of the board of water commissioners, are maintained on punch cards for use on an electronic computer. The current IBM listing shows the following amount of surface water for the various uses:

	Acre-feet
Domestic	113
Industrial	474, 423
Irrigation	234, 767
Municipal	87, 089
Recreational (Principally storage.)	430, 489
Commercial fish culture	16, 752
Total	1, 243, 633

Based on 1954 Agricultural Census and acceptable standards for uses by livestock, it is estimated that an additional 30,000 acre-feet annually is used from farm ponds and streams that is not included above.

2. From the report "Water for the Future" published by the Water Resources Policy Commission, which expired with the issuance of the report in late 1955, the following information on groundwater uses is furnished.

(*a*) Approximately 98 percent of the public water supply installations in Mississippi are from wells. More than 85 percent of the water used for municipal, industrial, and irrigation is derived from wells.

(*b*) Some people do not realize that Mississippi uses large quantities of ground water for irrigation purposes. In 1949, there were only about 25 irrigation wells in the Mississippi Alluvial Plain (Yazoo Dalta); but these increased to about 350 by 1954. Continued droughts brought the total number of irrigation wells to nearly 500 by early 1955. The recent normal rainfall years have slowed the increase in the number of irrigation wells being drilled, but one dry planting season will renew the drilling activity. In 1956, the irrigation uses from wells probably reached 500,000 acre-feet.

(*c*) Using 140 gallons per day per capita and an urban population of 1 million, we get an estimated 151,200 acre-feet of ground water for present municipal uses. Using 40 gallons per day per capita and a rural population of 1 million, we get an estimated 43,200 acre-feet of ground water for present rural home use.

(*d*) From the 1955 report "Water for the Future," we find that the industrial ground-water uses, including steam-electric plants, averaged 313,200 acre-feet.

(*e*) These tabulated ground-water uses total more than 1 million acre-feet annually, and do not include the many new industrial plants and other uses begun since 1954.

C. Fundamental problems

1. *Surface water.*—Mississippi's Water Rights Act of 1956 makes it possible for surface-water users to acquire definite water rights. Water can now be stored legally for use when stream flow is inadequate. The principal problem connected with the storage reservoirs is the lack of adequate overall planning.

Reservoir sites are limited in any given watershed and should be used for the best interest of all the people in the basin. Multiple uses for the stored water should be considered for each dam that is planned.

Under U.S. Public Law 566, Mississippi Board of Water Commissioners is serving as the sponsoring agency for a comprehensive land and water use study of certain river basins in the State. These studies are receiving complete cooperation from all interested agencies, both State and Federal, organizations, and individuals. These studies should be enlarged in scope and continued until the entire State is covered and work plans prepared and accepted by persons who will execute them.

2. *Ground water.*—Mississippi's Water Rights Act of 1956 does not apply to ground-water rights or usage. Landowners can drill wells and use as much ground water as they deem necessary, regardless of the effect on surrounding landowners.

Several areas in Mississippi have reported instances of flowing wells that have ceased to flow in recent years. Insufficient information prevents a determination of the exact ground-water conditions. Increased use has caused a local lowering of water levels, and the levels are continuing to fall. Information is needed on the overall ground-water budget. Are the supplies being used faster than they are being replaced?

The Board of Water Commissioners has requested additional State funds to match Federal funds for an increased program with the U.S. Geological Survey.

Recommendations have been made for the passage of a licensing law that would require water well drillers to file logs of certain wells.

It is anticipated that recommendations will be made to the 1962 Mississippi Legislature if present studies indicate the need for regulation of ground water uses.

In coastal areas of the State, large withdrawals of ground water have allowed salt water to encroach on the fresh-water supplies. This needs additional study.

3. *Flood control and drainage.*—Mississippi is making a study of its drainage laws in order to recommend revision of State laws in order to take full advantage of all the provisions of U.S. Public Law 566.

The comprehensive land and water use studies will provide material for a water management plan that begins with the top of the watershed and follows the routing of floodwaters to the Gulf of Mexico.

At the present time, there is a need for better coordination of efforts in routing these floodwaters. An overall plan for the entire basin must be made to prevent piecemeal work that will not be effective.

The lack of a full-time, adequately staffed, State agency to coordinate the water management plans of the various basins is the cause for the slow progress of the program.

For the information of the committee and its staff, copies of three reports are provided for the files. One, a report "Beneficial Use of Water in Mississippi," 1953; second, "Water for the Future," and, last, a copy of a report "Facts About Mississippi's Water Resources," 1958, containing a copy of the 1956 act. These are too bulky to be included in the record, but should be made available to this committee so that it might have access to a copy of our law, and the possibilities that our people envision through its application.

II. THE POTENTIAL OF WATER RESOURCE DEVELOPMENT

Raymond L. Nace, Associate Chief, Water Resources Division, U.S. Geological Survey, Washington, D.C., speaking at our nuclear future conference at Jackson, Miss., October 22, 1959, states: "The water situation in Mississippi is considerably more favorable than the national average. Precipitation is 53 inches (nearly twice the nationwide average). Natural evapo-transpiration is about 32 inches, or slightly more than 1.5 times the national average. But the residual theoretically manageable supply is 21 inches, or about 2.3 times the national average. Artificial consumptive use is only 0.2 inches, a negligible 1 percent of the manageable supply. Runoff to the gulf which is generated in Mississippi is nearly 21 inches."

This 21-inch runoff affords the total possible additional net development of 52.5 million acre-feet annually generated within the State. Additional development opportunities are afforded by Mississippi's 400-mile front on the Mississippi River.

Due to the topography and soil condition within the State, the maximum portion of this possible development is practical and economically feasible when a need arises.

III. PROJECTION OF FUTURE NEEDS

The exploding increase in population throughout the world will continue to increase the pressure on the production capacity of the arable soil resources. Other than the United States and some of the underdeveloped countries, the population of the world exceeds the capacity of the soil to meet the food and fiber requirements. Qualified sociologists tell us that two-thirds of the people of the world go to bed at night hungry.

The abundant agricultural production of the United States is not a curse, but a blessing. Political relationships eventually will become such that means of equitable distribution will be worked out, and the hungry peoples of the world can share our abundance.

The increasing population of the United States will in the next 25 years, place pressure upon our soil resources without the benefit of export markets. Within the next half century, we expect to increase three-fourths million acres presently irrigated within the State to a maximum potential of 7½ million acres. This would require an additional 10 to 12 million acre-feet of water developed in storage.

The industrial uses of water will increase substantially in Mississippi. Industry is dependent upon water for existence. The arid areas of the country are reaching their limits in water resources development and cannot continue their rapid development without running into water supply problems. The streams of the highly industrialized areas are becoming so contaminated that some industries requiring clean water are even now seeking new locations. Mississippi will offer adequate resources to the continued industrial expansion within the country to meet the needs of our growing population. We fully expect industrial water use to double in the next decade.

The use of water for municipal purposes will grow in excess of our industrial uses. Industry requires labor. Industrial growth will multiply population. People live in organized communities where water for human consumption, for sewage disposal, power, and other facilities, that go to make up our standard of living, are available.

We expect substantial industrial development and municipal growth in Mississippi in the years immediately ahead.

The present use of the water resources in the interior of our State in natural and artificial lakes, and our gulf coast, indicate a growing desire on the part of our people to use water for recreational purposes. Most of our surface water resources are currently used for recreation, and a great deal of it for other beneficial and profitable uses. We expect a continued growth in the use of these facilities. Our climate induces many visitors to come into our area every year to avoid the cold climate of our northern States.

MISSOURI

State of Missouri,
Executive Office,
Jefferson City, September 11, 1959.

Hon. Robert S. Kerr,
Senator, Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

Dear Senator Kerr: I wish to acknowledge receipt of your letter dated June 23, 1959, requesting information from my office on water matters in Missouri.

Enclosed you will find a statement discussing the Missouri Basin.

With all good wishes, I am,

Sincerely,

J. T. Blair, Jr., *Governor.*

Statement on Water Matters in the Missouri Basin

(By Gov. James T. Blair, of Missouri)

A conflict exists and seems to be gathering impetus over use of the water in the Missouri River. The 1944 Flood Control Act was supposed to resolve the conflict which existed over water for irrigation and navigation. It does not appear that any differences have been resolved. Instead, new conflicts have been added to the list that existed prior to enactment of Pulblic Law 834 by the 78th Congress, 2d session.

It is no surprise that these conflicts exist when one considers the unrelated interests which are in the Missouri Basin. In the lower portion of the basin we find a dense population with heavy industrial developments, while in the upper basin there is very little industrial development. The upper basin economy is geared almost entirely to agricultural operations, with some mining and oil production. There is need for irrigation in the upper basin States, while there is little need for irrigation in the densly populated portion of the Missouri Basin. The conflict of water for irrigation against navigation is not new. Many people here in Missouri and elsewhere feel that water for irrigation is in conflict with municipal and domestic use. Those concerned with the conservation of fish and wildlife see the problem in terms of its effect on their particular interest. Users of hydroelectric power view the subject as it applies to their business, and at this time are the most vociferous in presenting their claims.

There are several different Federal agencies deeply involved in the Missouri Basin and functions assigned to these agencies are often in conflict with each other. Often there is conflict between flood control and navigation. It seems there are numerous conflicts between several of the bureaus within the Department of the Interior. The Bureau of Reclamation, as the marketing agency for the hydroelectric power produced in the basin system, seems to have tremendous difficulty in reconciling the conflicts within its organization if the preference customers' complaints are to be relied upon.

Rivalry being as rampant as it is among the several Federal agencies, it is an amazing fact that there is not more conflict among the various water uses here in the Missouri Basin.

These conflicts cannot be resolved by the enactment of laws and application of political pressure. It may be too late to resolve many of these differences; however, many conflicts can be avoided by proper planning in advance of construction where all water uses receive consideration and the uses are planned and built with the proper emphasis on each use. There are examples of reservoirs being designed for flood control and power generation, yet there are great benefits attributed to recreation and the project is "sold" on the recreation benefits while designed entirely without consideration of the recreation potential.

An example of such a design is found in the Meramec Basin here in Missouri. Benefits attributed to this system of reservoirs were flood control and navigation with recognition that, with Metropolitan St. Louis in the proximity of this basin, recreation was greatly needed. It appears that recreation should have the first consideration in planning for a development in the vicinity of such a heavily populated area.

Our general assembly at its last session passed an enabling act which will permit the people in the Meramec Basin and vicinity to develop the recreational potential of the basin to the fullest extent. Under this act it is hoped that benefits from water resource development here in the State will be widespread and not restricted to such small segments of our population.

This enabling act requires that the benefits exceed the cost of the project. This postulation is on the theory that costs are real and that benefits must be realistic.

When the costs of a project are computed they are real, and if one desires to be accurate the estimate can be made with a very high degree of accuracy. There is an entirely different problem encountered when we try to estimate the benefits of the project. Benefits are not as easily or exactly determined as are costs, for we are looking into the future for many years. Benefits credited to a project often do not materialize upon completion of the planned works to the extent expected, and often problems are created which are worse than those existing before the project. Costs are real, yet we find benefits are often estimated on hopeful expectancy. This practice should be eliminated from all resource development programs, whether State of Federal.

The lack of uniformity in the methods used to compute benefits between the several Federal construction agencies should be eliminated, or at least there should be a serious effort made to improve them. This has been attempted through the use of the "green book," yet we find that basic laws under which the various agencies operate still permit them to use varying methods. This fundamental problem goes back to Congress and the laws they have enacted. Congress has never exerted the effort to enact any law to guide the policy of the various agencies in making economic analyses of resource projects. Most of the policy which covers this type of development is that which has been established by the several agencies. This fact is not conducive to comprehensive planning and indicates that Congress has been unwilling to assume the task of working out a sound economic approach to the problem of planning and developing our water and land resources.

The lack of a sound congressional policy leads to planning by compromise among the various Federal agencies rather than the development of our resources for the greatest national benefit. Often this results in the development for the benefit of a few people rather than the best good for the greatest number of people which it seems would be approaching that of national benefits.

All of this lack of coordination and noncooperation in present planning and development of our water resources cannot be attributed entirely to the lack of policy established by Congress. There is, in many States, a lack of interest or knowledge of what a comprehensive basin development should include. It seems that in many instances a State will gladly accept and work for a development program which may have negative benefits to their State and to the Nation. There are many instances where benefits did not materialize as expected or estimated. If the affected States had taken an objective attitude toward the proposal and had used the facilities of their several State agencies to study these plans, much disappointment and waste of resources could have been avoided. It would seem that it is the responsibility of the Federal construction agencies to safeguard these planning wastes, but they are not doing so at the present time. This is why it has become necessary that an independent review be made for water resource development proposals. There is no Federal agency to assume the responsibility, and when a State is unwilling to make an objective review, it is simply not made.

MONTANA

State of Montana,
Office of the Governor,
Helena, September 23, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

Dear Senator Kerr: Enclosed is a summary statement on the water problems of the State of Montana, as prepared by State Engineer Fred E. Buck.

It is submitted to you, in compliance with your request for such data, as chairman of the Senate Select Committee on National Water Resources.

Mr. Buck has done an excellent job of compiling this data, which took a great deal of time. Therefore, I hope that it will be given the fullest consideration in the deliberations of your committee and in the deliberations of the Congress concerning water problems which involve Montana.

Very truly yours,

J. Hugo Aronson, *Governor.*

Summary Statement on the Water Problems of the State of Montana

(Prepared by State Engineer Fred E. Buck)

Under the provisions of Senate Resolution 48, adopted April 20, 1959, there has been established the Senate Select Committee on National Water Resources to study the Nation's water problems.

The following data has been compiled by the State engineer's office in compliance with a request from said committee.

GENERAL INFORMATION

Montana is the fourth largest State in the Union, having an area of 147,138 square miles of which 1,260 square miles is water surface.

The Continental Divide, coursing northwest-southeast, cuts the State into two portions with each having distinctive characteristics. The western portion comprises about one-fifth of the area and is composed of valleys and timbered mountains, while the eastern four-fifths is rolling plains. The lowest elevation is 1,800 feet above sea level which is where the Kootenai River leaves the State in the northwest corner, and the highest elevation is Granite Peak which is 12,850 feet and is located near the northeast corner of Yellowstone Park. The plains area will range between 2,800 and 4,000 feet.

The annual precipitation varies greatly from 45 inches in the western part of the State to 9 or 10 inches in the plains area. The mean annual precipitation for the State as a whole averages 15 inches, about two-thirds of which falls during the growing season.

The largest source of income is agriculture and livestock followed by mining, manufacturing, and lumbering. Agriculture may be divided into two types, irrigated land and dry land. The irrigated area consists of about 2 percent of the State's total of 98,568,000 acres or a little over 1,800,000 acres. Dry agriculture land comprises about 14,283,000 acres. The lands classed as dry land are the areas where limited types of grains are grown without irrigation. The grazing area on the tax rolls for livestock comprises 36,834,000 acres. Besides this, livestock is dependent on irrigated land for winter feed. The forested area comprises 22,400,000 acres.

Montana has always been known as a producer of raw materials, there being little manufacturing until just recently.

The mountains of Montana supply a sizable proportion of the flow of the Columbia River to the west and the Missouri River to the east, and a small amount to Hudson Bay. Divide Mountain in Glacier Park is the only spot known on the North American Continent which supplies water to the Atlantic and Pacific Oceans and also to Hudson Bay.

The mountain streams in Montana are well known for their sparkling clarity, while some of the eastern streams are muddy.

The following data has been arranged in the same order as the outline submitted by the select committee and subject matter numbered in accordance with the committee outline of the first phase, I, II, and III.

I. STATEMENT OF THE EXISTING SITUATION AND PRESENT TRENDS, BY REGIONS

A. Summary of water resources available

All surface water originating in and flowing through Montana west of the mountains is tributary to the Columbia River. The Kootenai River originates in Canada, makes a loop in the northwest corner and flows back into Canada. Of the 9,860,000 acre-feet leaving Montana 2,468,000 acre-feet of this originates within the State. (See app. 1.)

The other stream leaving Montana on the west side is Clark Fork with many tributaries, some of the major rivers being Blackfoot, Bitterroot, St. Regis, and Flathead. All of these streams originate within the State except the North Fork of the Flathead which has its origin in Canada and supplies an annual average of 729,000 acre-feet flowing out of Canada. The net flow of the Clark Fork originating in Montana is 14,511,000 acre-feet.

On the east side of the mountains the streams all drain to the Missouri River. The main Missouri River is formed by the Madison, Jefferson, and Gallatin Rivers which unite at the town of Three Forks. The river flows from there northward to approximately Great Falls then turns eastward. Along the route there are many tributaries.

Streams along the north rim of the State drain into the Milk River which empties into the Missouri just below Fort Peck dam.

The southern part of the State is drained by the Yellowstone River and converges with the Missouri River just east of the Montana-North Dakota line. Practically all its tributary streams originate in Wyoming and flow northerly into the Yellowstone River.

The St. Mary River rises along the east border of Glacier Park and flows north into Canada. By the International Treaty of 1909 the waters of St. Mary and Milk Rivers are divided between the two countries according to a prescribed formula.

Along the Canadian border there is a total annual flow into Montana of the five streams crossing the border of 187,700 acre-feet.

Of the eight streams originating in Wyoming and flowing into the Yellowstone River there are 6,539,000 acre-feet originating in Wyoming. The net flow out of the State of the Missouri River of Montana origin is 8,253,000 acre-feet.

There is a small area in the northern part of Glacier Park that drains into Canada and thence into Hudson Bay. The water leaving Montana through the three rivers in this basin amounts to 863,000 acre-feet.

Of the total water flowing out of the State the percentages are as follows:

	Total leaving Montana	Originating in and not used in Montana
Missouri River Basin	36.6	33.6
Columbia River Basin	61.3	65.1
Hudson Bay Basin	2.1	3.3
Total	100.0	100.0

In all of the above figures there has been no correction made for the loss of water by evaporation or consumptive uses. Such figures, if they could be obtained, would be in addition to the recorded flows as enumerated above.

In the prairie area of the State east of the mountains agriculture is largely dependent on rainfall and ground-water supplies. Studies are constantly being made in order to inventory the underground aquifers. At the present time a small program of drilling wells and exploring aquifers is being done by cooperative agreement between the U.S. Geological Survey and the State school of mines and geology.

It has been estimated by the U.S. Geological Survey that the underground water supplies will exceed the surface water resources. In some areas it is necessary to depend upon water from wells to supply cities, towns, livestock, industries, and gardens. A very limited number of farms are irrigated by pumping from wells. In numerous cases of this type, irrigation is being done by sprinklers.

B. Statement on withdrawal and use of water

At the present time the greatest use of water is for irrigation, practically all of which is diverted from surface streams through canals, pipelines, etc.

The withdrawal from underground aquifers is very nominal at present in proportion to the use of surface water, but use from this source is gradually increasing.

The use of water for industrial purposes is small in comparison with agricultural use. The largest users at the present time are sugar beet plants, a paper pulp mill, oil refineries, smelting, canneries and dairying.

C. Fundamental problems

Perhaps the most fundamental problem in connection with the use of water is the system of acquiring water rights. There are no riparian rights. All rights are acquired by appropriation and use. There is no law of abandonment of a right nor is there any State central agency where water rights are recorded.

To acquire a right one files a notice of appropriation with the county clerk and recorder in the county where the water is to be used. He is not limited as to the amount of water he may file upon, nor is he required to file a statement of completion of facilities. His neighbor may acquire a right by diverting water and putting it to beneficial use without ever making a filing. This means that a search of water rights in any particular stream may entail inspection of the records in more than one county, and after such search has been made he still does not know how much water of the recorded rights was actually put to beneficial use nor has he any record of the rights acquired by use only. Under such a system we have no inventory of the amount of water being put to beneficial use in Montana.

About 15 years ago the State engineer undertook to prepare an inventory of our water uses. This work is known as the water-resources survey and is being completed by counties. At the present time 23 counties have been completed out of the total of 56. The time will come in the future when the water-resources inventory will be very valuable to Montana in protecting its rights against the encroachment on the water supply by lower States.

Another problem which is paramount is the constant effort being made by the Corps of Engineers and the Bureau of reclamation to create large storage projects in Montana for downstream benefits, such as, irrigation, navigation, power and flood control. Fort Peck is a good example of one that has already been built. There are numerous others proposed.

In place of building some of these large dams, Montana would receive far greater benefits with numerous small reservoirs which could be built along the headwaters of streams. These would supply a constant flow for irrigation during the growing season, and improve fishing, wildlife, and recreation. Careful planning should be carried out to the end that too many small reservoirs may not be built that would deplete the water supply for larger reservoirs that have already been constructed in the lower areas of the drainage basin.

The State of Montana has a water-conservation board which has carried on a very successful program of building irrigation projects and water supplies for small unincorporated towns. Under this plan the board has made water available for the irrigation of approximately 350,000 acres. Various sources of funds have been available for this purpose until recent years. All the moneys now come from appropriations by the legislature from the State's general fund. Under this plan the water users must repay the total cost of the projects without receiving any grants whatsoever for power, fish and wildlife, navigation, flood control, or recreation.

The board still has a list of projects that might be built, but due to inflation the last few years it is becoming more difficult to build such projects without grants of any kind. Said list of projects has been included with the list submitted by region 6, U.S. Bureau of reclamation.

The water-conservation board built two irrigation projects on the lower Yellowstone river supplied by pumping. The projects were almost identical in size. One was built under PWA loan and grant, the other by State funds. The board secured electrical energy from Fort Peck under the preference clause for the first project but has to pay the going rate for the second project because there was no Federal money involved. The explanation by the Department of the Interior for this discrepancy was not very satisfactory. The same taxpayers supplied money to build both projects but one project is discriminated against on account of having non-Federal funds involved.

This does not seem equitable and should be corrected.

A bill has been introduced in Congress to administer wilderness areas. Its provisions are very drastic in restricting the use of such areas. This bill, if passed, would practically forbid the construction of reservoirs, canals, or any other type of works for the use and conservation of water supplies. It would also prohibit the building of roads and removing diseased, overripe, or dead timber. Such a plan would be detrimental to Montana.

D. Ground-water problems

Bills have been introduced in the last four sessions of the Montana Legislature to create an underground water code but each time it has failed to pass.

Four years ago a small appropriation was made to the State school of mines and geology to be used in cooperation with the U.S. Geological Survey to investigate underground aquifers. Some progress has been made in this direction but it will take much larger appropriations and considerable time before the underground water resources are very well known.

A bill was passed 12 years ago requiring logs of artesian wells to be filed with the State engineer, and 2 years ago a bill was passed providing for the filing of logs of all wells drilled with the county clerk and recorder in the county in which the well was completed.

E. Water use for Pollution abatement

Four years ago the legislature passed a measure creating a State pollution council which would have control over all water pollution measures. The council has classified most of the major streams as to purity and the best uses to be made of such streams. As most of the streams are clear and unpolluted the standards set are high and efforts are being made to maintain these standards.

Probably the worst polluted stream in the State is the Yellowstone River which receives effluent from the cities along the river, oil refineries, sugar plants, meatpacking plants, canneries, railroad yards, etc. Considerable effort is being made by all parties concerned to eliminate these different types of pollution to bring the stream back to a high standard. Cooperation in this direction has been excellent.

There is no place in Montana where a stated flow of a stream is being maintained for the sole purpose of diluting pollution. This practice would certainly be an unwarranted waste of water.

The streams are clear and pure in comparison with similar streams in many other States.

Senator Murray has requested the State board of health to prepare a statement for the select committee on this subject.

II. PROJECTIONS OF FUTURE DEMANDS FOR WATER AND WATER RELATED ACTIVITIES CONSIDERING RELATIONSHIPS OF AVAILABILITY AND COSTS (SUPPLY-DEMAND RELATIONSHIPS)

A. Population projections

(See app. 2, prepared by the State planning board.)

B. Municipal water use

Senator Murray has asked the State board of health to prepare a statement for the select committee on this subject.

(See app. 3 prepared by the State board of health.)

C. Agricultural use of water

As stated above there are now 1,800,000 acres of land under irrigation.

A survey was recently made to determine the potential irrigable land and the resulting depletion of the water supply that may be developed by the year 2010, west of the mountains. The survey shows that 55,000 acres can be developed along the Kootenai River which will deplete the water supply by 59,000 acre-feet, and 645,000 acres can be irrigated along the Clark Fork Basin which will deplete the water supply of the Clark Fork River by 882,000 acre-feet.

Such a careful survey has not been made east of the mountains but a conservative estimate would be that approximately 2 million more acres might be irrigated east of the mountains. The only data available on this subject is obtainable from the booklet entitled "Adequacy of Flows in the Missouri River," April 1959 (pp. 21 to 36), prepared by a subcommittee of the MBIAC.

Under good farm management an average of 2 or 2½ acre-feet applied to the land should be sufficient to raise crops. Twice this amount would be diverted to take care of seepage, waste, evaporation and return flow. Return flow is the water diverted but unused and eventually finds its way back to the stream for reuse.

In some areas where poor farming is practiced or where subdrainage is abnormal, as much as 7 to 10 acre-feet per acre is being diverted. This is a waste of water that could be corrected by better farming practices.

The Soil Conservation Service has done an excellent job in reclaiming land by assisting farmers in clearing brush, building drains, canals, laterals, and reservoirs. Also the Service has assisted in giving instructions on contour plowing and strip farming on dry agricultural areas.

D. Water needs of industries

(See app. 2 prepared by the State planning board.)

E. Electric energy

The greater share of electrical energy used in Montana is from hydrodevelopment. Practically all of the private hydropower is generated and distributed by the Montana Power Co. Two dam and power sites, Noxon Rapids and Cabinet Gorge, on the lower Clark Fork River, are owned and operated by the Washington Water Power Co. Power from these two sites is tied into the Bonneville grid and distributed mostly to the lower States. (See app. 4.)

The U.S. Bureau of Reclamation generates and distributes public power from three damsites, the Canyon Ferry and Fort Peck Dams on the Missouri River, and the Hungry Horse Dam on the South Fork of Flathead River. The Hungry Horse plant is tied into the Bonneville grid but a considerable amount of the power is sold wholesale to the Anaconda Aluminum Works at Columbia Falls and the Victor Chemical Co. near Butte.

In addition to the hydroelectric plants there are nine steam and internal combustion plants having a total installed capacity of 126,568 kilowatts. (See app. 5.) Power is used extensively for pumping irrigation water, city water supplies, sprinkler systems, and industries.

Montana is nearly all covered by rural electrification lines. They have no powerplants of their own but purchase wholesale from the operating private and public powerplants.

There is considerable feeling among the REA co-ops in eastern Montana against the ruling of the Department of Interior as to the amount of power that will be available at Fort Peck for use by the local REA cooperatives. The powerplant is being doubled in size but only about 20 percent of the capacity is tentatively allocated to use by the local cooperatives. The balance of the power flows to preferred customers in lower States.

The power system of the Montana Power Co. is tied in with the Bonneville power grid and energy is transferred back and forth as required. Fort Peck has one generating unit of 15,000 kilowatts which is also tied into the Bonneville grid.

There is an area in southeastern Montana that is becoming short of power and has very little sources of power available except the proposed Yellowtail Dam on the Big Horn River. The demand for power in that area is increasing.

On the west side of the mountains there are numerous large potential hydroplants which may be built. If so, Montana is very anxious to reserve blocks of power from these sites for use within the State, but it is very probable that the demands within the State may not exist at the time these various powerplants are completed. Since the water originates in Montana and the powerplants are located within the State, it seems only reasonable and equitable that a reservation of power for use within Montana should be made.

F. Navigation

About the only navigation in Montana is rafting saw logs on Flathead Lake. There are a few excursion boats that operate during the tourist season. One is at the Gates of the Mountains on the Missouri River and another is an excursion down the Missouri River from Fort Benton to Fort Peck, and another one or two on Flathead Lake.

Montana is interested, however, in navigation on the Columbia and Missouri Rivers outside of the State. When the dams and locks on Snake River are completed, navigation to the Pacific Ocean will be available from Lewistown, Idaho, which will be within reasonable hauling distance to western Montana as soon as the highway is completed down the Lochsa River.

Slack water navigation on the Columbia River does not require heavy drafts on Montana's water supplies, but navigation on the Missouri River is run-of-the-river type which means a heavy drawdown on Fort Peck Reservoir during the navigation season. This creates large mudflats around the shoreline in which cattle become mired down and where resorts, cabins, and boat docks are left high and dry. There is considerable ill feeling in eastern Montana in regard to this situation.

If slack water navigation could be installed on the lower Missouri River, a great deal of this difficulty could be eliminated and there would be more water available at Fort Peck for the generation of power which is badly needed.

G. Flood control

Montana does not have serious flood problems such as are experienced in many other States. Our problems are rather minor and localized to small areas. Whenever a problem of this sort arises, we must depend on the Corps of Engineers to remedy the situation as there is no State money or organization legalized to take care of flood problems.

H. Water recreation

There is a great deal of use of water for recreation in Montana. Fishing is excellent on all of the streams and lakes, and a great deal of activity is rapidly developing in boating and water skiing. On many lakes and streams resorts are being built to accommodate boating and fishing.

I. Fish and wildlife

Montana is blessed with fish and wildlife and it has an excellent organization, the fish and game department, which is doing everything possible to protect this natural resource.

Many kinds of game fish are found in the lakes and streams. Large game animals consists of deer, antelope, bears, lions, bobcats, mountain sheep, mountain goats, elk, moose, caribou, and a few buffalo. For the last few years there has been an open season on all of these animals except caribou and only one year for buffalo.

Small fur-bearing animals and both upland and lowland birds are very plentiful. Ducks and geese nest in Montana, and the flyway between Canada and Mexico crosses the State.

One chief factor that is detrimental to fish and game is the encroachment on streams and lakes by dams and irrigation projects which often interferes with spawning habits of fish and winter habitat of large game.

J. Trends in use of water for waste disposal

The use of water for disposal of waste for both municipalities and industries has been gradually on the increase. The State planning board for the last 4 years has been actively engaged in encouraging new industries to come into the State. As this program grows there will be an increase of water use, but just how rapidly this increase will come about is anybody's guess.

III. MEANS OF MEETING FUTURE DEMANDS (NEW TECHNIQUES)

A. Conventional methods of adding new supplies and costs thereof

Our conventional methods of adding new water supplies consists chiefly of building reservoirs which will conserve water during the flood season for use in the summer when the streams are normally low. The unit costs per acre-foot of storage will vary greatly depending upon the type of dam, availability of material, and accessibility.

B. Vegetational management (reduction of evapotranspiration)

The State has not carried on a program of vegetation management. It is possible that the U.S. Forest Service is doing some work of this type. The agricultural college at Bozeman has made some studies of this kind.

C. Weather modification (induced precipitation)

A few years ago there was considerable activity in trying to induce precipitation by artificial means but the results were not satisfactory, and at the present time this is not being practiced in Montana.

D. Evaporation reduction and seepage control

The State is not attempting to carry on a program of reducing evaporation of streams and reservoirs. To control seepage considerable work has been done in Montana by the use of bentonite for canal linings.

E. Desalinization

Work of this nature is not being done in Montana.

F. New techniques in multiple-purpose river management

The State engineer is the State representative on the technical committees which manage the water supplies on both the Columbia and Missouri Rivers.

The objectives of these committees is to study the anticipated flows from snow surveys and then by planning the use of reservoirs to minimize as much as possible flood damages and at the same time provide sufficient storage to take care of power, navigation, fish and wildlife, and recreation.

G. Effects of nuclear energy

Nothing can be said on this subject.

H. New technical methods of improving water supply methods (improved ground water use, water recovery, etc.)

(*a*) Better farming methods.
(*b*) Use of sprinkler systems.
(*c*) Construction of reservoirs.
(*d*) Canal lining.
(*e*) Drainage works.
(*f*) More use of wells.
(*g*) Improving watershed areas.
(*h*) Purifying brackish water.
(*i*) Consolidating parallel canals.
(*j*) Exchanges of water, or water rights.
(*k*) Slack water navigation on the Missouri River.
(*l*) Cleaning canals.
(*m*) Treating sewage and industrial wastes.
(*n*) Lowering the evaporation from reservoirs.
(*o*) Improve regulation of storage for power and flood control.
(*p*) Improve estimates of runoff from snow surveys.
(*q*) Conservation of artesian water.
(*r*) Prevent contamination of underground water.
(*s*) Meter all municipal and industrial water use; abolish flat rates.

APPENDIX No. 1

INVENTORY OF WATER ORIGINATING IN AND NOT USED IN MONTANA

Missouri River Basin

[Average annual flow in acre-feet]

Missouri River near Williston (1928–57)	14, 900, 000
Little Missouri River (estimated net flow from Montana)	80, 000
Flow out of Montana	14, 980, 000
Flow into Montana—	
From Wyoming:	
Madison River	343, 900
Yellowstone River	2, 197, 000
Clarks Fork Yellowstone	669, 700
Bighorn River	2, 580, 000
Lttle Bighorn River	103, 500
Tongue River	292, 000
Powder River	335, 900
Little Powder River	17, 000
Total from Wyoming	6, 539, 000
From Canada:	
Milk River tributaries	147, 000
West Fork Poplar River	3, 200
Middle Fork Poplar River	15, 000
East Fork Poplar River	10, 900
Big Muddy Creek	11, 600
Total from Canada	187, 700
Total from out of State	6, 727, 000
Net flow of Montana origin leaving State	8, 253, 000

[Average annual flow in acre-feet]

	Leaving Montana	Originating in Canada	Originating in Montana
Columbia River Basin:			
Kootenai River	9, 860, 000	7, 392, 000	2, 468, 000
Flathead River		729, 000	
Clark Fork	15, 240, 000		14, 511, 000
Total Columbia River Basin	25, 100, 000	8, 121, 000	16, 979, 000
Hudson Bay Basin:			
Waterton River	193, 000		193, 000
Belly River	179, 000		179, 000
St. Mary River	491, 000		491, 000
Total, Hudson Bay Basin	863, 000		863, 000

Summary of water of Montana origin not used in Montana

[Average annual flow in acre-feet]

	Entering Montana	Leaving Montana	Originating in and not used in Montana
Missouri River Basin	6, 727, 000	14, 980, 000	8, 253, 000
Columbia River Basin	8, 121, 000	25, 100, 000	16, 979, 000
Hudson Bay Basin	0	863, 000	863, 000
Total	14, 848, 000	40, 943, 000	26, 095, 000

APPENDIX 2

[From Montana Business, July 1957]

MONTANA'S INDUSTRIAL, POPULATION, AND EMPLOYMENT PROBLEMS AND THEIR RELATION TO WATER

(By Perry F. Roys, Director, Montana State Planning Board)

If we look at industrial, population, and employment problems we find that they are intimately related to water, and that the relationship is a very important one so far as Montana is concerned.

Montana's basic industries are almost exclusively resource-oriented and fall within the classification "primary." Agriculture is the predominant source of income in the State, with mining, manufacturing, and lumbering following in that order. They are the foundation for other dependent industries such as trade and services, transportation, communication, public utilities, and finance. What happens, therefore, to the basic income sources individually or collectively has strong repercussions through the State's economy. This importance is best shown by the close relationship that gross basic income has to income payments to individuals and retail sales in the State. In a study conducted by the Bureau of Business and Economic Research at Montana State University, it was shown graphically for the period from 1935 through 1951 that a change of $1 million in gross basic income would cause one to anticipate changes in individual income payments and retail sales of $1.4 million and $887,000 respectively, in the same direction during the same year. To say it another way, whenever an existing or new agricultural, mining, lumbering, or manufacturing industry adds $1 million to the State's gross basic income, it can be expected that individual income payments to Montanans will increase on the order of $1.4 million and that retail merchants in the State will sell in the neighborhood of $900,000 more merchandise.

Emphasis is given to these factors because Montana has long sought new industry to stabilize and diversify the State's economy, and we are still searching, though some notable progress has been made in recent years. It is my opinion that in this search in the years ahead we will have to increase our rate of industrial growth substantially over what we have had in the past if we are to make progress on an equal basis with the rest of the Nation. My reasons for this view will be shown more fully in my later discussions on population and employment.

The point I wish to make at the present time is that industrial development potentials of large scale which we have in the State are to a large extent confined to resource-oriented industries of the primary group, similar to those we now have. This means that we are most likely to have more mines, electrometallurgical plants, sawmills, food processing installations, meatpacking plants, oil refineries, hydroelectric and steam electric facilities, chemical industries, various types of wood product fabricating plants, pulp and paper operations, and possibly such things as small iron and steel operations.

Now, let's consider population. At the time of the 1950 census, Montana, with a population of 591,024 inhabitants, ranked 42d among the States. At the same time, it had a population density of 4.1 persons per square mile. For the United States as a whole, population density in 1950 was 50.7 persons per square mile.

More important than these figures are those which tell us what happened before and after 1950. Going back to 1920 and tracing the decennial percentage changes, we find that in the decade from 1920 to 1930, Montana was the only State to experience a population decrease. This amounted to a 2.1 percent decline, as compared with a 16.3 percent increase for the Nation as a whole. There was an increase of 4.1 percent from 1930 to 1940, against the national average of 7.2 percent, and in the decade ending in 1950 the State grew by 5.6 percent while the Nation was growing 14.5 percent.

No official census has been made since 1950, but there are some estimates available, which can bring us up to date. As of July 1, 1956, the U.S. Bureau of the Census estimated that Montana's population had increased to 638,000 for an 8 percent gain over 1950. This was still under the national gain during the same period, estimated at 10.9 percent. Using the estimates of the State board of health, based on school census reports, however, a more favorable relationship is achieved. These figures show that as of the end of 1956, the State had grown to 675,000 population, which amounts to a 14.2-percent increase since 1950. If correct, Montana in recent years has increased its population at a faster rate than has the Nation as a whole

This, however, is not the complete story, for in the decade from 1940 to 1950 there was about a 3-percent decline in the number of persons in the age group between 15 and 64 years, which constitutes the labor force. Apparently, this situation is still occurring because from 1950 to 1953 the Census Bureau estimates a decline of 2.5 percent in the 18 to 64 age group.

What lies ahead so far as population growth is concerned? Here we can only guess, but at least there are some guides for us to follow. A couple of years ago the National Association of Manufacturers estimated that Montana's population in 1965 would be 693,000. Stanford Research Institute at about the same time estimated 680,000. Probably these are too low, for growth in recent years, as described previously, probably occurred at a faster rate than any estimates with which I am familiar. Let's assume, therefore, that we want to continue to grow at about our rate since 1950. This amounts to about 14,000 per year. If realized, it would mean that our population in 1965 would be in the neighborhood of 800,000 based on projections from the State board of health estimate of 675,000 population for 1956.

In the face of past instability in our population growth, and continued evidence of outmigration among our productive age groups, it would appear that Montana is going to have to do more in the way of using the State's productive resources than it has done in the past, if this population goal is to be achieved. Leaving you with this thought for the time being, let's turn to employment.

Many factors affect the size and growth of the labor force, but the predominant one is the number of job opportunities reflecting the state of economic health. Here are the highlights of the past so far as Montana is concerned Bureau of Census figures show that our total labor force grew from 214,200 in 1920 to 232,200 in 1950. This was a net gain of 18,000. During the period substantial declines occurred in employment in some of the basic industries, the most significant being in agriculture which declined by approximately 30,000, from a peak of 85,000 in 1920 to 55,000 in 1950. Substantial declines also occurred in mining, manufacturing, construction, transportation communications, and utilities. Since there was a net gain in total employment, these losses were more than offset by gains in other nonagricultural fields. These occurred principally in trade, finance, services, miscellaneous, and Government. If losses in the period are added to the net gain actually experienced, it means that approximately 55,000 new job opportunities came into being during the 30-year period. On the average, then, it was necessary to have in the neighborhood of 1,500 new jobs each year.

There are certain conclusions which can be drawn from the facts just related. First, new job opportunities have to come from nonagricultural employment because agriculture, in terms of employment, is still a declining industry. Second, declines occur within the nonagricultural segment and these have to be replaced by new nonagricultural opportunities. Third, we have not done too badly during past years because employment in trades, services, miscellaneous, and Government has increased more than the total losses which occurred in agriculture and in some of the nonagricultural industries. This situation probably cannot be expected to continue at past levels, however, because growth in these latter areas generally lags behind growth which occurs in basic income sources. It is my opinion that trades, services, etc., have pretty well overtaken the growth which has occurred in the basic industries. Continued expansion of employment in nonagricultural activities is therefore probably more dependent on further expansion of the basic industries than it has been since the end of World War II

Let's look to the future, then. Total nonagricultural employment in the State in 1955 was in the neighborhood of 160,000. Projections of employment needs for the decade from 1955 to 1965, with which I am familiar, estimate that for the Nation as a whole nonagricultural employment will have to increase from 25 to 40 percent. Using the low figure, this means that if Montana is to keep pace with the Nation we will need to have 200,000 persons engaged in nonagricultural industries by 1965. This amounts to an increase of 4,000 jobs per year. Growth of this magnitude is a sizable task in view of the fact that from 1920 to 1930 we added about 1,500 jobs per year, and in the relatively prosperous period from 1950 to 1955 we added jobs at the rate of approximately 2,000 per year. Consequently, there is a formidable task before us if we are to replace job losses occurring with continued technological progress and if we are to reverse the outmigration which is occurring in the productive age groups, to say nothing of overcoming the sharp seasonal fluctuations in employment with which Montana has long been plagued.

It should be remembered that this prospective employment need is probably conservative. In making the estimate the low side of the 25 to 40 percent projected increase in employment needs for the Nation as a whole was used. Further evidence of conservatism is found if the State's present labor force is compared with the present population. Average employment figures for the current period indicate that over 37 percent of the population is in the labor force.

Montana business indexes [1]

[1947-49=100]

	Nonagricultural employment	Carloadings	Electric power consumption	Copper production	Zinc production	Crude oil production	Bank debits	Department store sales	Agricultural prices	Retail food prices (May 1950=100)
1947	96.3	104.0	94.6	100.6	86.3	96.5	89.9	94.8	102	----------
1948	101.3	99.1	99.4	100.9	111.3	103.0	103.8	103.5	105	----------
1949	102.4	97.0	106.0	98.4	102.4	100.6	106.3	101.7	93	----------
1950	103.8	103.8	112.5	95.0	128.3	89.3	117.4	104.1	100	----------
1951	105.2	110.2	114.9	99.8	143.3	98.6	128.6	107.9	118	114.8
1952	108.2	112.9	127.9	107.3	154.8	105.4	134.6	114.0	108	116.0
1953	108.9	119.3	140.9	134.9	151.6	131.1	133.9	111.0	89	113.0
1954	109.5	115.7	122.6	103.2	115.1	156.5	140.5	112.1	88	114.5
1955	113.1	125.7	169.6	141.7	129.6	172.6	153.8	118.8	85	107.7
1956	r 115.4	136.8	223.4	168.4	135.8	239.3	166.0	p 126.3	----------	108.1
1956:										
May	117.9	129.0	224.8	170.1	158.7	231.3	153.1	117.2	81	105.0
June	123.6	132.0	221.7	166.5	145.0	240.9	165.2	114.9	81	112.5
July	124.1	147.2	213.0	155.5	130.2	248.2	167.8	117.8	82	113.9
August	125.4	151.5	221.5	167.1	123.4	236.9	165.0	137.9	82	108.0
September	124.9	157.4	224.1	182.3	132.2	232.5	174.5	137.9	82	112.4
October	122.6	163.5	221.6	184.7	119.8	240.9	191.2	145.8	81	108.5
November	118.6	155.1	227.5	176.6	121.9	264.3	182.0	154.4	82	111.5
December	116.7	128.1	225.9	158.4	123.3	275.9	175.5	216.7	81	108.4
1957:										
January	112.3	109.6	222.9	170.4	96.8	275.1	168.4	75.2	81	108.6
February	111.4	116.8	232.0	194.5	113.8	286.8	156.5	82.6	82	108.9
March	112.0	116.3	217.2	190.0	114.0	292.8	160.3	103.8	83	108.9
April	115.1	120.5	227.5	r 161.2	r 132.6	290.8	168.5	123.9	85	106.7
May	r 119.1	129.3	224.5	p 147.3	p 107.1	299.3	156.9	120.8	85	109.1
June	p 121.3	----------	212.9	----------	----------	----------	173.0	----------	85	108.8

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[1] See June issue for explanatory footnotes.

The next step then is an evaluation as to where approximately 4,000 jobs per year are to come from. This I tried to describe by implication in my discussion of the industrial character of the State. There it was my conclusion that the majority of new industrial opportunities would have to be created as a result of further developments in basic resource-oriented industries.

Resource-oriented industries which we now have in Montana and those which we are most likely to have are relatively heavy users of water. That this is so can be substantiated in a couple of ways. Presently, for example, it is estimated that the amount of water used industrially in the State is in excess of 5 billion gallons per day. This compares with 120 billion gallons per day for the Nation as a whole. Thus, over 4 percent of the Nation's industrial use of water occurs in Montana, yet the percentage of the Nation's industrial activity, in terms of income and employment, which takes place in the State is substantially less. This is not especially difficult to understand when recognition is made of the fact that processing of raw materials typically requires large volumes of water, and there is a consequent low dollar value added per gallon used. For example, over 7,000 gallons of water are needed to make a barrel of gasoline; and between 20,000 and 40,000 gallons are required in the manufacture of a ton of pulp.

Despite the large volume now used, it would appear, at least upon superficial examination, that Montana has plenty of water for further expansion and development of heavy water-using industries because we estimate that there is an average of approximately 36 billion gallons of water leaving the State each day. Furthermore, there would seem to be little cause for concern about adequate supplies for industry for a long time to come, because water used industrially, like that used for municipal purposes, is mostly nonconsumptive. But is this abundance of water for industry in Montana the whole story?

Industries do not locate new plants on the basis of average waterflows, but rather must base their needs for water on minimums. To give you a case in point, the Clark Fork River at one point had an average annual flow of 5,000 cubic feet per second for the 25-year period from 1930 through 1955. Yet the minimum flow of record was less than 400 cubic feet per second. Thus, for practical purposes, only a small proportion of the mean annual flow is available for year round industrial use.

Qualitative aspects are also important. To illustrate, industry uses water for processing, cooling, and effluent disposal purposes—uses which are for the most part nonconsumptive. Use, even though nonconsumptive, may limit the capacity of a stream to support productive endeavor to use of amounts substantially less than is indicated even by minimum flow figures. This is so because alteration of water which results from chemical change, introduction of solids, changes in temperature, or other causes may make it uneconomic, if not impossible, to use the water again for other purposes for great distances. Consequently, water quality is an important determinant of the amount of usable supply. In turn, the quantity available for dilution purposes has a bearing upon what happens to the quality. So it can be seen that quantity and quality are interdependent factors, and this gives further emphasis to the importance of minimum flow as a controlling factor in the amount of productive endeavor that any given location on a stream may be able to support.

This takes me back to the quantitative considerations. I wish I could say precisely where we are now in Montana so far as present use is concerned, and where we can go from here with what we have. Unfortunately, I cannot. But it can be said that a comparison of the estimated present use for industrial purposes of over 5 billion gallons per day against the possibility that 36 billion gallons are leaving the State daily is not especially comforting when account is taken of the way in which minimum flows in combination with present and contemplated uses can restrict the amount of productive endeavor that a particular water course can support. This is particularly apparent when recognition is made of the situation now existing on the Yellowstone at Billings and below, where our State board of health is endeavoring, through cooperation with industry and municipalities, to eliminate and reduce sources of pollution. If this is not done, other things being equal, is there not some possibility that this area of the State is already near the point at which it will be difficult to either acquire or permit further development of resource industries requiring water availability under economic conditions? Or take the case of the Clark Fork in the Missoula vicinity and below. How much further development can it support, and how long will it be before the maximum possible under existing flow conditions is achieved?

These, and other questions which could be asked, give emphasis to the concept that water is a limiting factor to development, and that limit so far as specific areas in the State are concerned may be approaching faster than we think. To say it another way, such questions should alert us to a recognition of the reality that how Montana progresses in the future in our ability to provide employment opportunities depends to a large extent upon water which we have and how we use it.

The importance of this recognition is best expressed by looking to future demands for water. The U.S. Department of Commerce, Business and Defense Services Administration, estimates that for the Nation as a whole total water use in 1975 will exceed that of 1955 by nearly 75 percent. Over the same period, industrial use is expected to increase by 92 percent. Consequently, if Montana's growth follows the average for the Nation, it will mean that at least 10 billion gallons per day will be used industrially by 1975. But it is probable that demands could be greater since we are still a water surplus State, relatively speaking, and our towns along the major river systems should become increasingly attractive as locations for resource-oriented industries requiring large amounts of water.

Where will these additional supplies come from? Some progress will undoubtedly be made by industries, municipalities, and others in using water in the years ahead, in the way of reducing requirements, eliminating and preventing stream pollution, and water reclamation. Reliance on these methods alone, though, will likely fall far short of providing the additional supplies needed to meet the projected increases in demand. There must, therefore, be aggressive action to increase absolute quantities by regularizing the flow of streams. By building dams, then, there is the best insurance that water will not become a limiting factor to economic development in Montana. Regularizing streamflows can increase presently effective minimum flows many times, making more water available for use and for dilution purposes in effluent disposal, as well as eliminating the large amounts now going to waste each year.

This does not mean that all upstream storage projects that are physically possible are necessarily economically feasible. This must be determined in each case by careful evaluation and comparison of the benefits to be derived and the loss and expense to be incurred in flooding a reservoir site. In the same way, every project that is economically feasible may not necessarily be timely, so some priority must be established on the basis of need. But because of the stimulating effect that water development has on economic development and the long periods of time it takes to increase the availability of water supplies, projects should be undertaken within a schedule of priority well in advance of demonstrated need. With such a broad approach, it is my opinion that Montana's water resources can play an even more vital role in progress for people of the State than the advancements that have been achieved by upstream storage in the past. **Water need not be a limiting factor to our economic development if we take the necessary steps to avoid it.**[1]

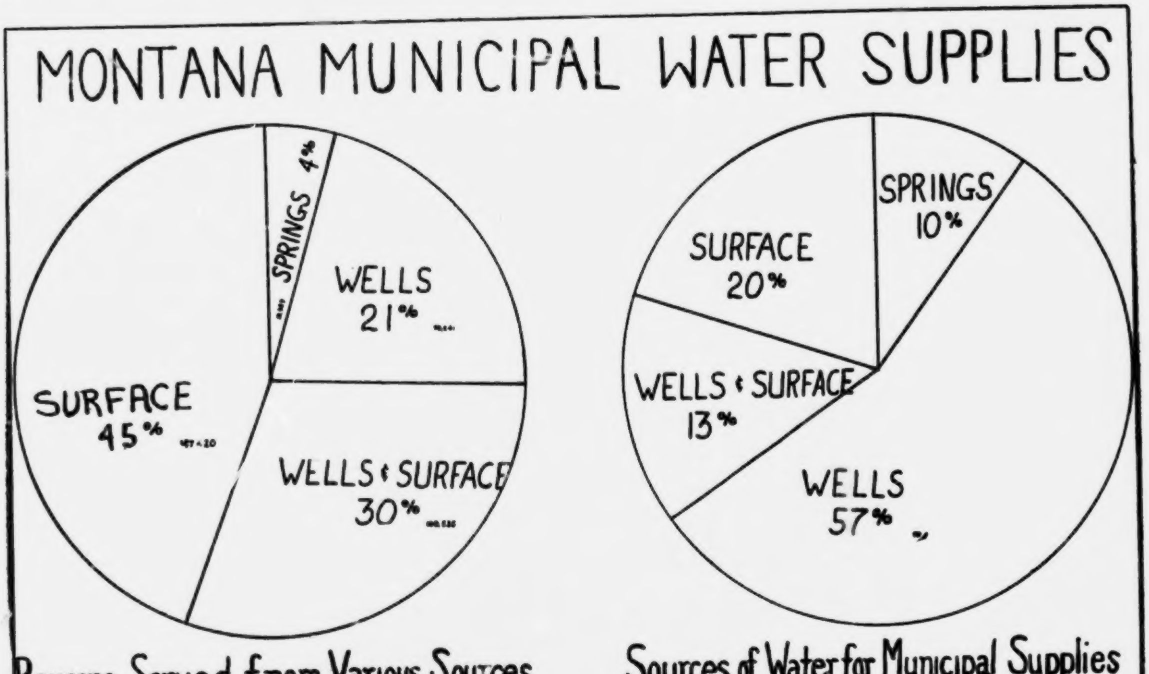
Value of construction contracts, Montana, 11 Western States and the United States, first 6 months, 1956 and 1957

[Thousands of dollars]

	June			Total 6 months		
	1956	1957	Percent change	1956	1957	Percent change
Montana, total	9,591	13,905	45	107,674	69,927	−35
Residential building	4,881	5,057	4	24,356	23,362	−4
Nonresidential building	3,623	3,236	−11	20,663	22,050	7
Heavy engineering construction	1,087	5,612	416	62,655	24,515	−61
11 Western States,[1] total	620,693	819,335	32	3,400,568	3,765,674	11
United States, total	2,947,483	3,243,486	10	16,193,228	16,958,005	5

[1] Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Source: F. W. Dodge Corp., in cooperation with the Bureau of Business and Economic Research, Montana State University.



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[1] This article is based upon a talk given by Mr. Roys before the Second Annual Water Resources Conference on the Montana State University campus June 28–29.

APPENDIX No. 4

Hydroelectric plants in Montana

Plant	Company	Installed capacity kilowatts
COLUMBIA RIVER BASIN		
Lake Creek-Troy	Montana Light & Power Co.	4,500
Big Fork	Pacific Power & Light Co.	4,150
Noxon Rapids	Washington Water Power	[1] 336,000
Flint Creek	Montana Power Co.	1,000
Kerr	do	168,000
Milltown	do	3,0[illegible]
Thompson Falls	do	30,000
Hungry Horse	U.S. Bureau of Reclamation	285,000
Total Columbia River Basin		831,690
MISSOURI RIVER BASIN		
Black Eagle	Montana Power Co.	16,800
Cochrane	do	48,000
Hauser Lake	do	17,000
Holter	do	38,400
Madison	do	9,000
Morony	do	45,000
Mystic Lake	do	10,000
Rainbow	do	35,600
Ryan	do	48,000
Canyon Ferry	U.S. Bureau of Reclamation	50,000
Fort Peck	Corps of Engineers	85,000
Total Missouri River Basin		402,800
Grand total for entire State		1,234,490

[1] Under construction.

APPENDIX No. 5

Steam and internal combustion plants in Montana

Plant	Company	Capacity kilowatts
Anaconda	Anaconda Copper Co.	2,100
Hardin	Holly Sugar Corp.	1,300
Baker	Montana-Dakota Utilities	1,000
Glendive	do	7,000
Miles City	do	2,600
Frank Bird	Montana Power Co.	60,000
Libbey	J. Neils Lumber Co.	5,650
Sidney	Montana-Dakota Utilities	44,000
Shelby	Marias River Electric Co-op., Inc.	2,918
Total for the entire State		126,568

NEBRASKA

State of Nebraska,
Lincoln, September 28, 1959.

Senator Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: As the Nebraska official who is responsible for the administration of the State's water laws, I am very much interested in the work of the Select Committee on National Water Resources and I appreciate this opportunity to present my views on the subject.

The State of Nebraska is the only State that is wholly within the Missouri River Basin. In addition to the Missouri River, which forms its eastern boundary, the State is well served by a network of streams originating both outside and within its borders. The principal river basins and the Nebraska area within each of them are as follows: Platte, 20,000 square miles (exclusive of Loup and Elkhorn); Republican, 9,700 square miles; Niobrara, 9,800 square miles; Loup, 15,700 square miles; Elkhorn, 7,000 square miles; Blue, 7,230 square miles; White and Hat Creek, 2,100 square miles; and minor Missouri River tributaries, 6,100 square miles. All but the first three are entitely within Nebraska. Acompanying this statement is a copy of a map entitled "Present and Proposed Irrigation—1950" which shows the location of the various basins and streams and the areas irrigated. Also enclosed is a copy of "Irrigation Map of Nebraska," January 1, 1958.

Nebraska is so situated that it experiences a wide range of climatic conditions. The climate ranges from semiarid in the west to subhumid in the east. The average precipitation at the western boundary is about 15 inches while at the eastern boundary it is slightly over 30 inches. Based on the records for the 10-year period, 1946–55, the total mean annual inflow to the State is about 1.2 million acre-feet and the mean annual outflow is approximately 9 million acre-feet. The mean annual consumptive use on lands irrigated from surface water supplies averages about 1¼ million acre-feet. This does not take into account the consumptive use of water on nonirrigated lands nor that on lands irrigated by pumping from ground water.

Some irrigation has been practiced in the State since the days of the earliest settlers, and some statutory water law has been in effect since 1877. The appropriation doctrine was adopted in 1889 and in 1895 a comprehensive water code, based on the appropriation doctrine, together with an Irrigation District Act, was adopted by the legislature. These 1895 acts, with amendments, are still in effect.

Early irrigation projects were strictly run-of-the-stream developments and it soon became evident that only those with the very earliest priorities could have a reliable water supply during critical periods. Storage water made available by the reservoirs of the U.S. Bureau of Reclamation's North Platte project has firmed up the supply for more than 300,000 acres of rich irrigated lands in Nebraska's North Platte Valley. The 2 million acre-foot Lake C. W. McConaughy, completed in 1941 by the Central Nebraska Public Power and Irrigation District, and the Sutherland Reservoir of the Platte Valley Public Power and Irrigation District furnish a full supply of water for about 130,000 acres of irrigable lands within the central district and an adequate supplemental supply of water for more than 150,000 acres of old lands inadequately supplied by natural flow rights.

The Bureau's Box Butte Reservoir on the Niobrara River supplies some 13,000 acres in the Mirage Flats project. The Bureau's Enders, Swanson Lake, and Harry Strunk Lake, and the Corps of Engineers' Harlon County Reservoirs, all recently constructed as part of the Missouri Basin project, are supplying more than 100,000 acres of lands in the Republican River Basin. Project type irrigation developments in the Loup River Basin now in operation account for another 55,000 acres with a full water supply. Numerous small community gravity diversion enterprises and individual pumps from surface streams supply an additional 200,000 acres with a full or partial irrigation supply.

Hydroelectric plants on the Platte and Loup Rivers with 135,000 kilowatt total installed capacity generate some 500 million kilowatt-hours annually. A substantial part of the water is used for irrigation after it passes through the powerplants.

Except for the city of Omaha, which derives its municipal water supply from the Missouri River, only two towns, with a combined population of about 7,000, depend upon surface streams for their municipal water. All of the other municipalities and farmsteads are adequately supplied with ground water.

Virtually the only industrial use of surface waters is confined to its use for cooling purposes in steam powerplants. There is relatively little industry in the State at this time and any water used in connection with it is mainly pumped from the ground water.

Nebraska is blessed with an unusually abundant supply of good quality ground water which may be obtained in usable quantities at relatively shallow depths in nearly all localities except in the extreme eastern part of the State. Besides its use throughout the State for domestic, municipal, and industrial supplies, as noted before, it is widely used for the irrigation of lands. At this time there are some 23,000 irrigation wells in the State furnishing a water supply to about 1,750,000 acres. In an average year the yields from irrigated lands in the State are from two to three times those of similar dry lands. The present trend during years of relatively normal weather conditions is toward annual increases of 25,000 to 30,000 acres in land irrigated from ground water.

Nebraska's large-scale irrigation development from surface water supplies has been done under the sponsorship of local irrigation or reclamation districts, organized under State law. Except for the early run-of-the-river projects, which were generally locally financed, these projects have been built by the Bureau of Reclamation under repayment contracts with the local districts. Notable exceptions are five operating public power and irrigation projects which were financed with PWA funds, under a loan and grant arrangement, and constructed by local districts. Funds for the repayment of PWA loans is derived from revenues from the sale of electrical and water services.

Funds are available for the Bureau of Reclamation to start construction of new facilities to furnish water for a total of about 85,000 acres of lands now dry-farmed in the Ainsworth and Farwell projects. Planning by the Bureau is in progress on proposed projects covering more than 300,000 additional acres to be served from surface supplies not now used for irrigation. All of these projects are certain to be costly and some of them may not be economically feasible. In any event, they will be beyond the ability of the sponsoring districts to finance locally.

It is my understanding that the several Federal agencies will develop detailed information for your committee relative to water supplies, potential irrigation development, flood control, recreation, pollution abatement, and other water uses, so I shall not attempt to cover these items in detail. Nebraska has a relatively abundant supply of both surface and underground water. There is some evidence of overdevelopment of ground water irrigation in some small areas. However, legislation enacted in the 1959 legislature provides for the setting up of local districts to govern withdrawals in critical areas and it may be effective in properly controlling ground water use.

There is no indication that any municipality will not be able to supply the requirements of growing populations in the future. The Nebraska Constitution and statutes gives domestic use of water a preference over its use for irrigation and manufacturing, so that, if necessary, prior rights for the latter two uses may be condemned for domestic use.

In the operation of the federally constructed reservoirs in the Republican River Basin some releases have been made in the interest of pollution abatement. However, when full development is reached on the irrigation projects which rely on storage in the said reservoirs for their supplemental water, such releases will need to be curtailed. It is my feeling that pollution of streams should be avoided by the installation of adequate sewage treatment plants and other controls, particularly in this semiarid region where the use of water for irrigation and other beneficial purposes is so vital to the welfare and economy of the area.

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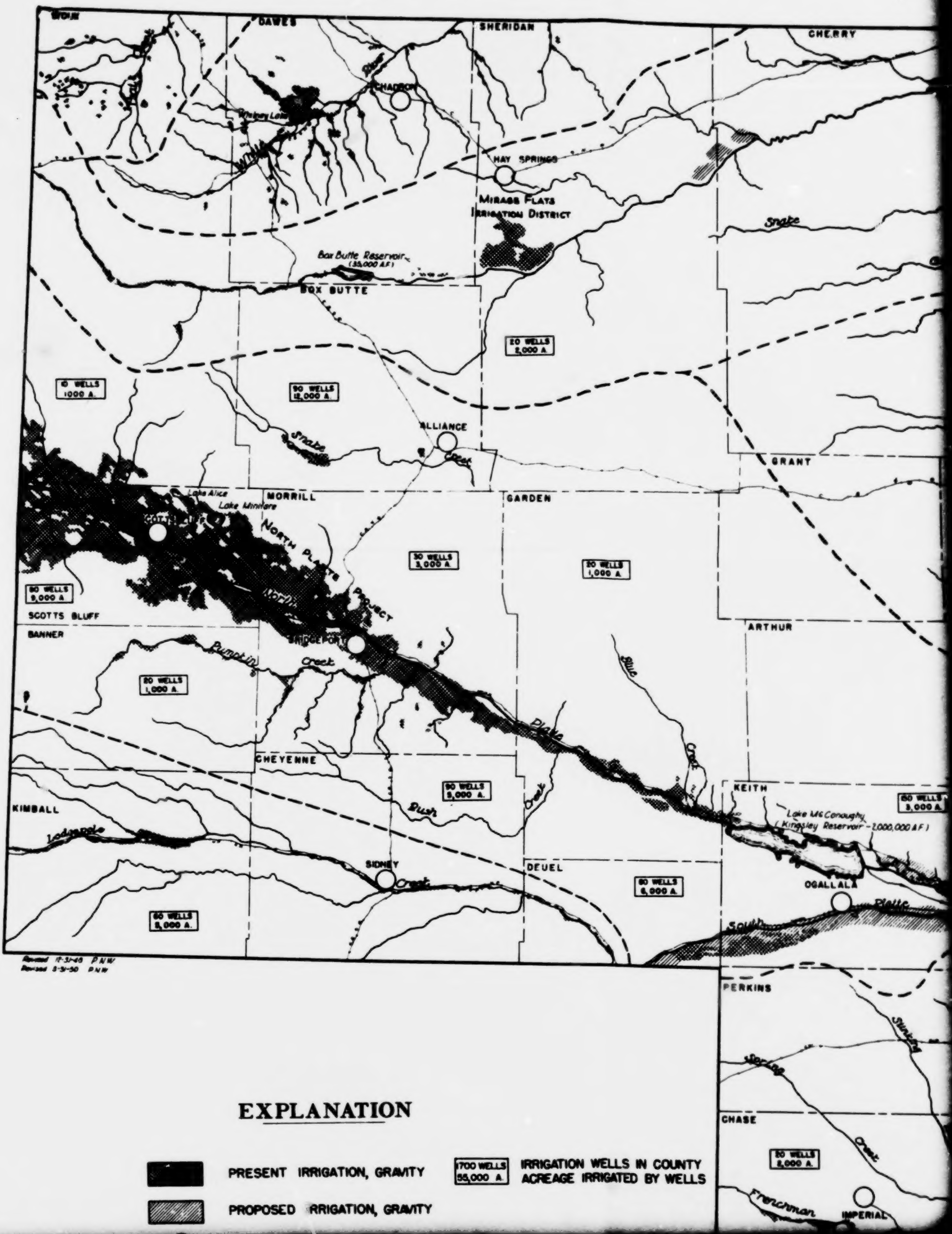
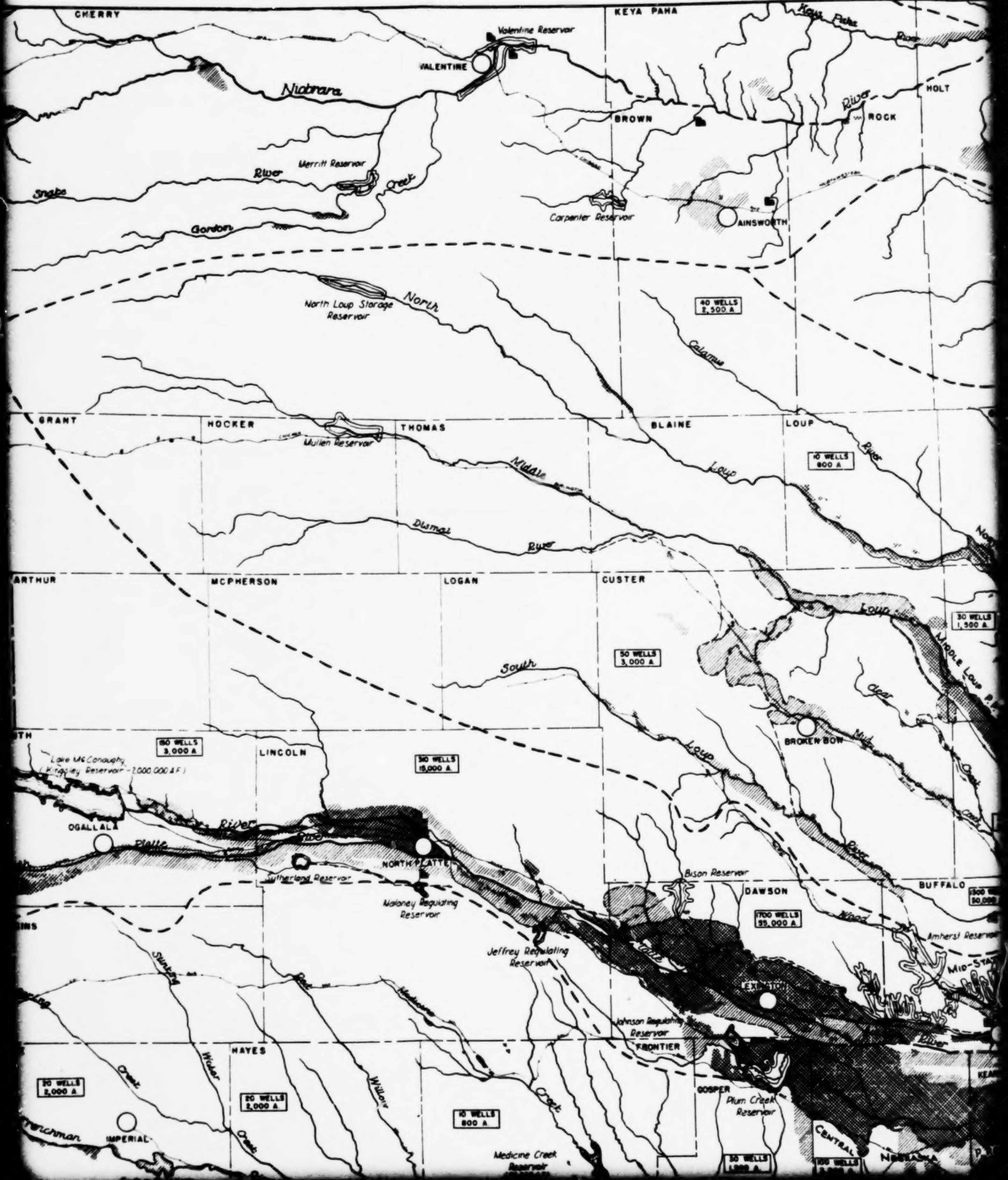


SIOUX
DAWES
SHERIDAN
CHERRY
CHADRON
Whitney Lake
White
HAY SPRINGS
MIRAGE FLATS IRRIGATION DISTRICT
Snake
Box Butte Reservoir (35,000 A.F.)
BOX BUTTE
20 WELLS 2,000 A.
10 WELLS 1000 A.
90 WELLS 12,000 A.
ALLIANCE
Snake
Creek
GRANT
MORRILL
GARDEN
Lake Alice
Lake Minitare
SCOTTSBLUFF
NORTH PLATTE PROJECT
North
30 WELLS 3,000 A.
20 WELLS 1,000 A.
80 WELLS 9,000 A.
SCOTTS BLUFF
BANNER
ARTHUR
BRIDGEPORT
Pumpkin Creek
20 WELLS 1,000 A.
Blue Creek
Platte
CHEYENNE
90 WELLS 9,000 A.
Rush Creek
KIMBALL
Lodgepole
KEITH
150 WELLS 3,000 A.
Lake McConaughy (Kingsley Reservoir - 2,000,000 A.F.)
SIDNEY
Creek
DEUEL
80 WELLS 6,000 A.
OGALLALA
South Platte
60 WELLS 5,000 A.
Revised 11-31-48 PNW
Revised 3-31-50 PNW
PERKINS
Stinking
Spring
CHASE
Creek
20 WELLS 2,000 A.
Frenchman
IMPERIAL

EXPLANATION

- ■ PRESENT IRRIGATION, GRAVITY
- ▨ PROPOSED IRRIGATION, GRAVITY
- 1700 WELLS 55,000 A. — IRRIGATION WELLS IN COUNTY, ACREAGE IRRIGATED BY WELLS

PRESENT AND PROPOSED IRRIGA



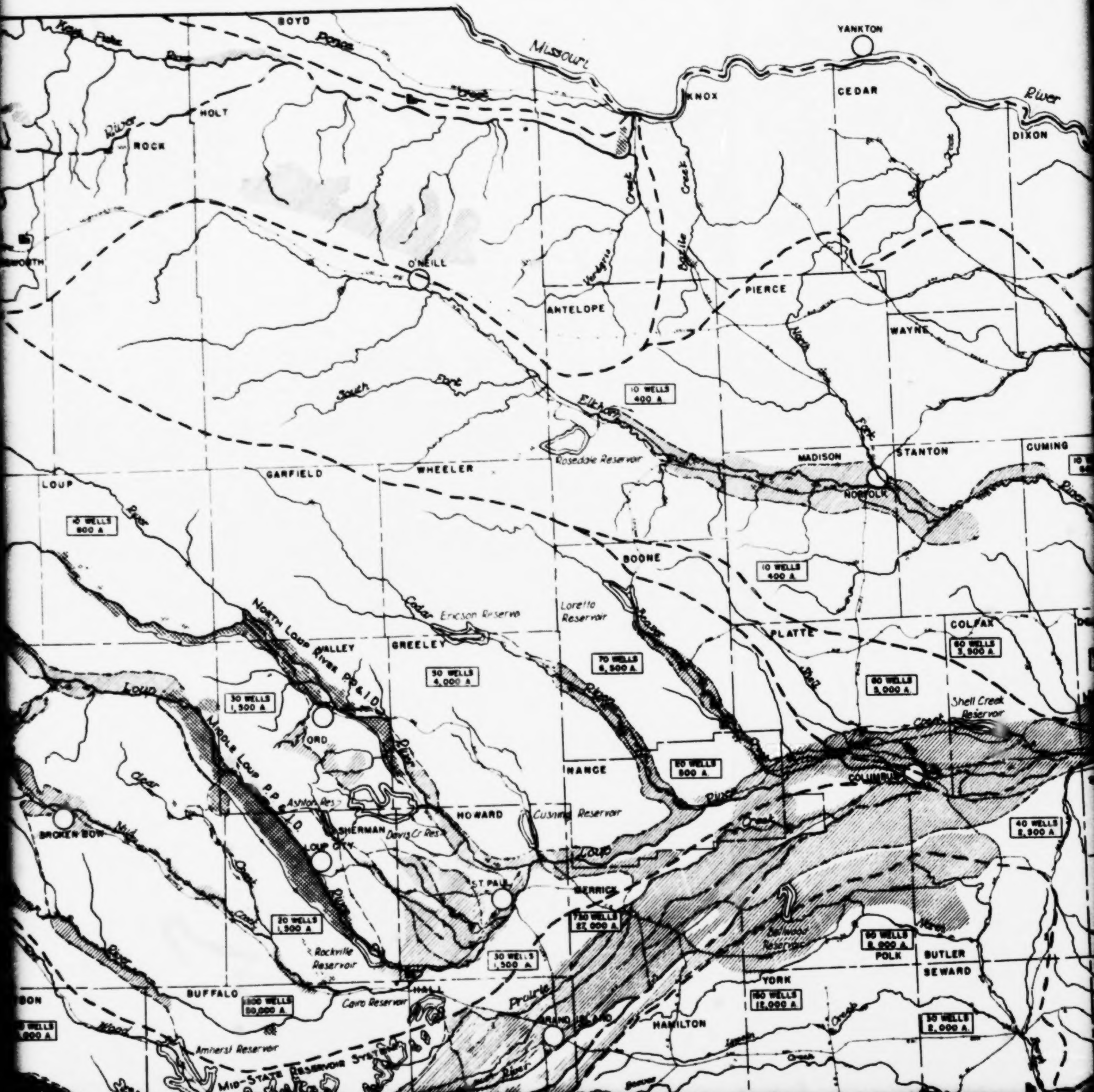
CHERRY
KEYA PAHA
Keya Paha River
Valentine Reservoir
VALENTINE
Niobrara
River
HOLT
BROWN
ROCK
Merritt Reservoir
Snake
River
Creek
Gordon
Carpenter Reservoir
AINSWORTH
North Loup Storage Reservoir
North
40 WELLS 2,500 A
Calamus
GRANT
HOCKER
THOMAS
BLAINE
LOUP
Mullen Reservoir
Middle
Loup
River
10 WELLS 800 A
Dismal
River
ARTHUR
MCPHERSON
LOGAN
CUSTER
Loup
30 WELLS 1,500 A
MIDDLE LOUP
50 WELLS 3,000 A
South
Clear
BROKEN BOW
Mud
Creek
150 WELLS 3,000 A
Lake McConaughy (Kingsley Reservoir - 2,000,000 A.F.)
LINCOLN
300 WELLS 15,000 A
OGALLALA
Platte
River
NORTH PLATTE
Sutherland Reservoir
Loup
River
Bison Reservoir
DAWSON
BUFFALO
1700 WELLS 55,000 A
Maloney Regulating Reservoir
Wood
Amherst Reservoir
MID-STA
Jeffrey Regulating Reservoir
Platte
LEXINGTON
Stinking
Red
Medicine
Johnson Regulating Reservoir
River
FRONTIER
HAYES
Willow
Creek
Creek
Creek
KEA
20 WELLS 2,000 A
20 WELLS 2,000 A
10 WELLS 800 A
GOSPER
Plum Creek Reservoir
Frenchman
IMPERIAL
Medicine Creek Reservoir
CENTRAL
NEBRASKA
50 WELLS
100 WELLS

B

NEBRASKA

C

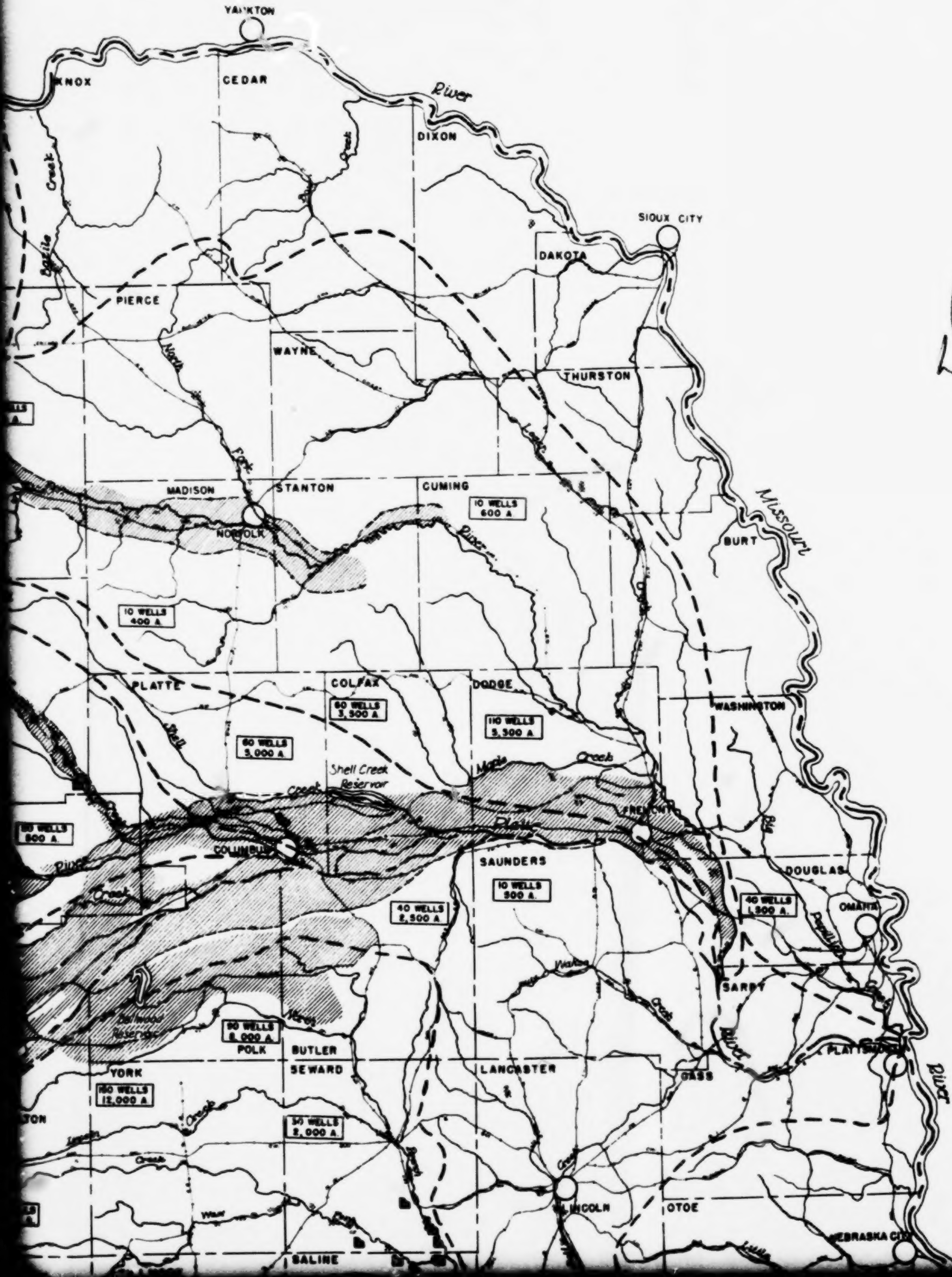
ED IRRIGATION 1950

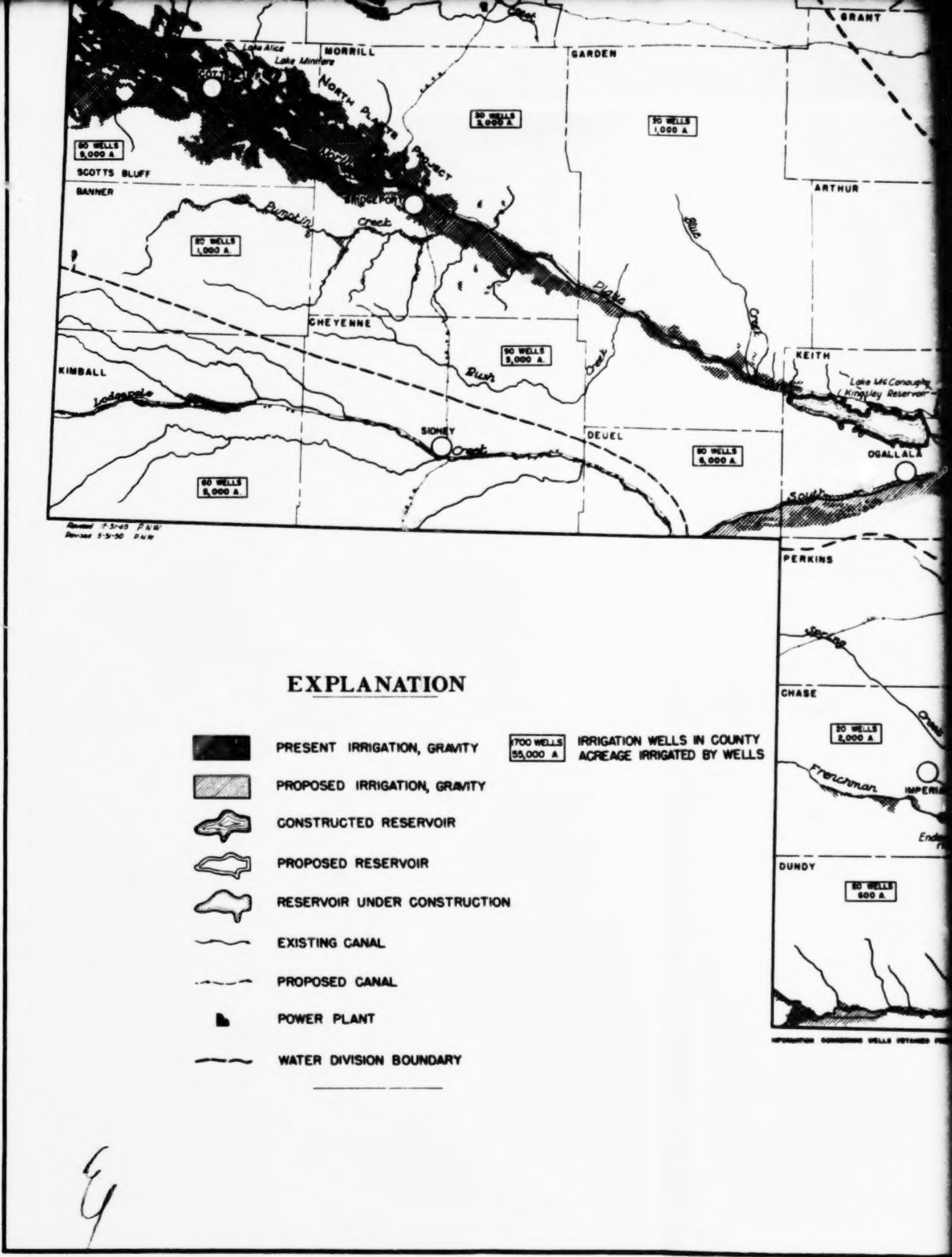


BOYD
Keya Paha River
Ponca Creek
Missouri River
YANKTON
KNOX
CEDAR
DIXON
HOLT
ROCK
O'NEILL
Verdigre Creek
Bazile Creek
ANTELOPE
PIERCE
WAYNE
10 WELLS 400 A
South Fork
Elkhorn
Rosedale Reservoir
MADISON
STANTON
CUMING
NORFOLK
LOUP
GARFIELD
WHEELER
10 WELLS 800 A
BOONE
10 WELLS 400 A
Cedar
Ericson Reservoir
Loretto Reservoir
PLATTE
COLFAX
60 WELLS 3,500 A
NORTH LOUP VALLEY RIVER P.P.&I.D.
GREELEY
30 WELLS 4,000 A
70 WELLS 6,500 A
60 WELLS 3,000 A
Shell Creek Reservoir
Loup
30 WELLS 1,500 A
ORD
MIDDLE LOUP P.P.&I.D.
NANCE
20 WELLS 800 A
COLUMBUS
Ashton Res.
SHERMAN
Davis Cr Res.
HOWARD
Cushing Reservoir
BROKEN BOW
LOUP CITY
ST. PAUL
MERRICK
40 WELLS 2,500 A
730 WELLS 27,000 A
20 WELLS 1,300 A
Bellwood Reservoir
90 WELLS 8,000 A
POLK
BUTLER
SEWARD
Rockville Reservoir
30 WELLS 1,300 A
YORK
BUFFALO
1800 WELLS 50,000 A
Cairo Reservoir
HALL
150 WELLS 12,000 A
50 WELLS 2,000 A
Prairie Creek
GRAND ISLAND
HAMILTON
Amherst Reservoir
MID-STATE RESERVOIR SYSTEM
Wood River

C

D

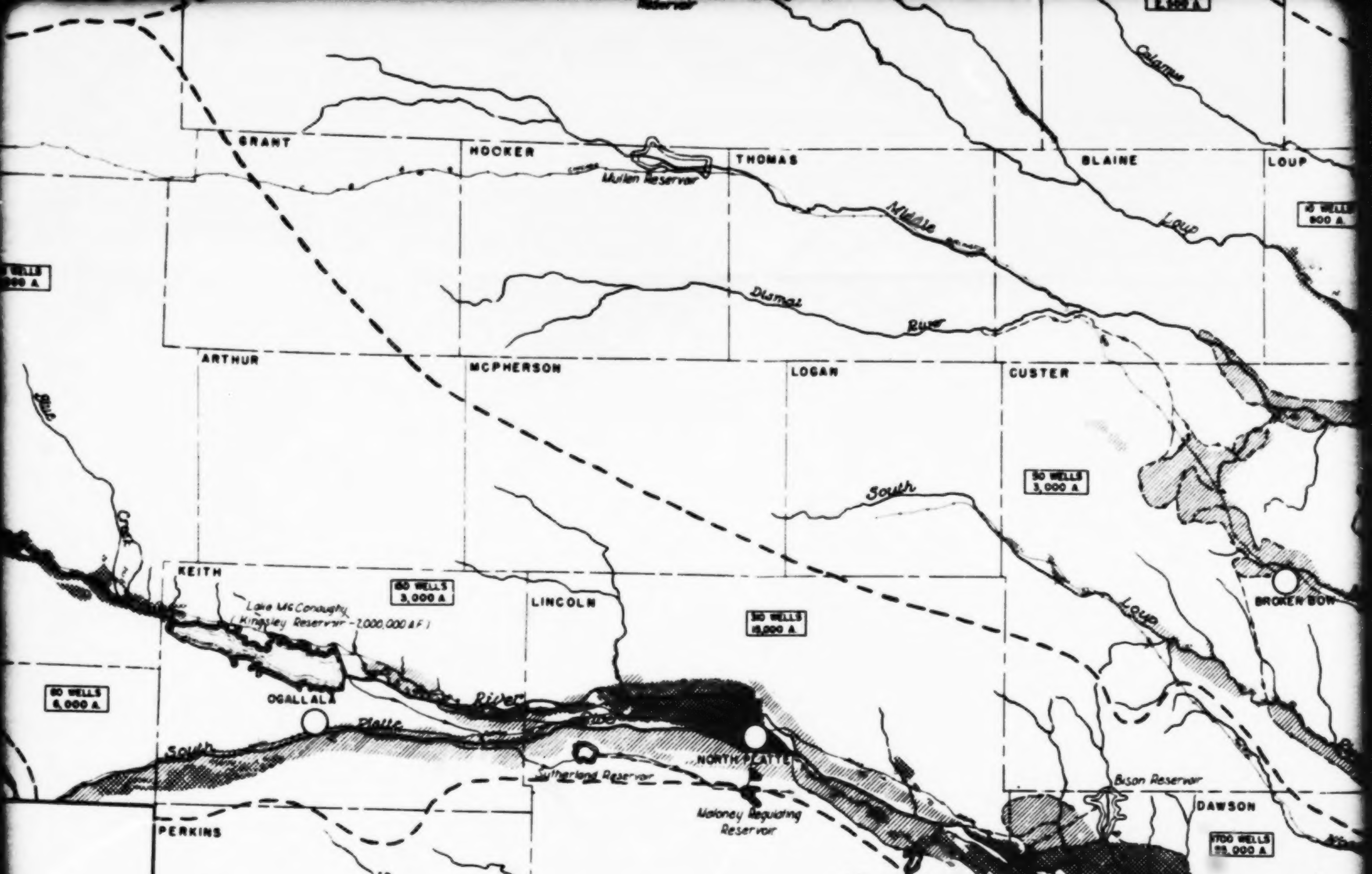

YANKTON
KNOX
CEDAR
River
DIXON
SIOUX CITY
DAKOTA
PIERCE
WAYNE
THURSTON
MADISON
STANTON
CUMING
10 WELLS 600 A
NORFOLK
River
BURT
Missouri
10 WELLS 400 A
PLATTE
COLFAX
60 WELLS 3,500 A
DODGE
110 WELLS 5,300 A
WASHINGTON
60 WELLS 5,000 A
Shell
Shell Creek Reservoir
Creek
Maple Creek
FREMONT
Platte
80 WELLS 800 A.
COLUMBUS
River
Creek
SAUNDERS
10 WELLS 500 A.
DOUGLAS
40 WELLS 1,500 A
OMAHA
40 WELLS 2,500 A
Bellwood Reservoir
Wahoo Creek
SARPY
90 WELLS 8,000 A.
POLK
BUTLER
PLATTSMOUTH
YORK
SEWARD
LANCASTER
CASS
150 WELLS 12,000 A.
Creek
30 WELLS 2,000 A.
Lincoln
Creek
River
LINCOLN
OTOE
NEBRASKA CITY
SALINE


GRANT
Lake Alice
Lake Minitare
MORRILL
GARDEN
SCOTTS BLUFF
NORTH PLATTE PROJECT
North Platte
20 WELLS 2,000 A.
20 WELLS 1,000 A.
90 WELLS 9,000 A.
SCOTTS BLUFF
BANNER
ARTHUR
BRIDGEPORT
Pumpkin Creek
20 WELLS 1,000 A.
Blue Creek
Platte
CHEYENNE
90 WELLS 9,000 A.
KEITH
KIMBALL
Lodgepole
Rush Creek
Lake McConaughy (Kingsley Reservoir)
SIDNEY
Creek
DEUEL
90 WELLS 6,000 A.
OGALLALA
60 WELLS 5,000 A.
South
Revised 12-31-48 P N W
Revised 5-31-50 P N W
PERKINS
Spring
CHASE
Creek
20 WELLS 2,000 A.
Frenchman
IMPERIAL
Ende
DUNDY
20 WELLS 600 A.
INFORMATION CONCERNING WELLS OBTAINED

EXPLANATION

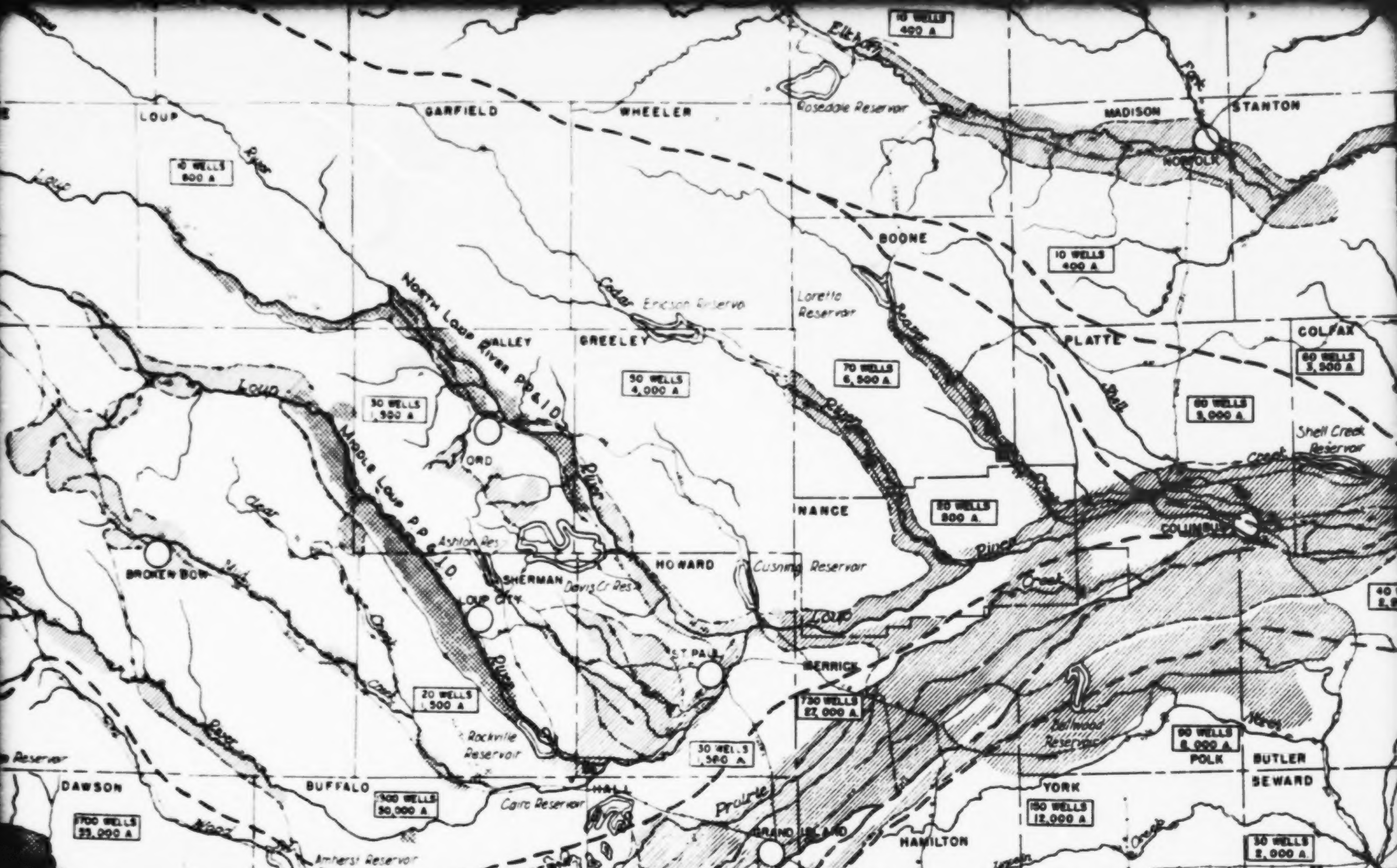
PRESENT IRRIGATION, GRAVITY
PROPOSED IRRIGATION, GRAVITY
CONSTRUCTED RESERVOIR
PROPOSED RESERVOIR
RESERVOIR UNDER CONSTRUCTION
EXISTING CANAL
PROPOSED CANAL
POWER PLANT
WATER DIVISION BOUNDARY
1700 WELLS 55,000 A
IRRIGATION WELLS IN COUNTY
ACREAGE IRRIGATED BY WELLS

63198 O - 61 (Face p. 198) No. 1


GRANT
HOOKER
THOMAS
BLAINE
LOUP
Mullen Reservoir
Middle Loup
Dismal River
Calamus
10 WELLS
900 A
ARTHUR
MCPHERSON
LOGAN
CUSTER
South Loup
50 WELLS
3,000 A
KEITH
150 WELLS
3,000 A
Lake McConaughy
(Kingsley Reservoir - 2,000,000 A.F.)
LINCOLN
310 WELLS
16,000 A
BROKEN BOW
60 WELLS
6,000 A
OGALLALA
South Platte
North Platte River
NORTH PLATTE
Sutherland Reservoir
Maloney Regulating Reservoir
Bison Reservoir
DAWSON
1700 WELLS
95,000 A
Jeffrey Regulating Reservoir
LEXINGTON
Johnson Regulating Reservoir
FRONTIER
PERKINS
Stinking Water Creek
Spring Creek
Red Willow
Medicine Creek
LLS IN COUNTY
TED BY WELLS
CHASE
20 WELLS
2,000 A
HAYES
20 WELLS
2,000 A
10 WELLS
800 A
GOSPER
Plum Creek Reservoir
Central
Frenchman
IMPERIAL
Enders Reservoir
(76,000 A.F.)
Medicine Creek Reservoir
(95,000 A.F.)
Red Willow Reservoir
30 WELLS
1,500 A
100 WELLS
3,300 A
DUNDY
HITCHCOCK
RED WILLOW
FURNAS
10 WELLS
600 A
40 WELLS
2,500 A
CAMBRIDGE
Frenchman - Cambridge Irrigation District
TRENTON
McCOOK
30 WELLS
2,000 A
BENKELMAN
Republican
Swanson Reservoir
40 WELLS
2,500 A
Sappa Creek
Beaver Creek
Harlan County Reservoir
(850,000 A.F.)

INFORMATION CONCERNING WELLS OBTAINED FROM CONSERVATION & SURVEY DIVISION U.N. & U.S. GEOLOGICAL SURVEY   COUNTIES WITH LESS THAN TEN WELLS NOT SHOWN

D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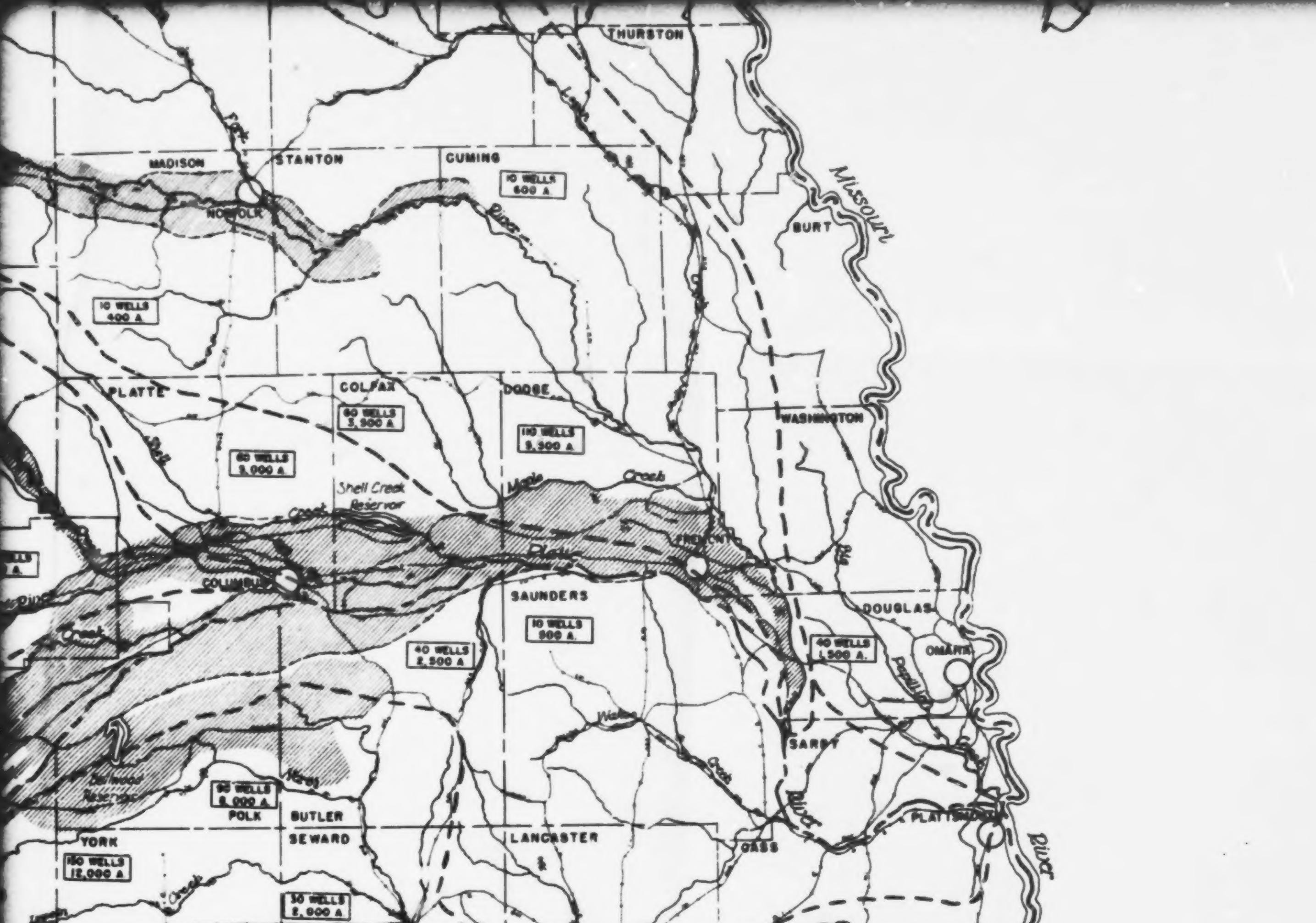
Elkhorn
Roseaale Reservoir
MADISON
STANTON
NORFOLK
LOUP
GARFIELD
WHEELER
10 WELLS 600 A
Loup
River
BOONE
10 WELLS 400 A
Cedar
Ericson Reservoir
Loretto Reservoir
North Loup Valley
North Loup River PP&I.D.
GREELEY
PLATTE
COLFAX
60 WELLS 3,500 A
Loup
Middle Loup P.P.&I.D.
30 WELLS 1,500 A
50 WELLS 4,000 A
70 WELLS 6,500 A
60 WELLS 5,000 A
Shell Creek Reservoir
Shell Creek
ORD
River
NANCE
50 WELLS 800 A
COLUMBUS
Ashton Res.
BROKEN BOW
SHERMAN
Davis Cr. Res.
HOWARD
Cushing Reservoir
LOUP CITY
Loup
River
Creek
ST. PAUL
MERRICK
20 WELLS 1,500 A
730 WELLS 27,000 A
Rockville Reservoir
30 WELLS 1,560 A
Bellwood Reservoir
90 WELLS 8,000 A
POLK
BUTLER
SEWARD
Reservoir
DAWSON
BUFFALO
900 WELLS 50,000 A
HALL
Cairo Reservoir
1700 WELLS 25,000 A
YORK
150 WELLS 12,000 A
Prairie
GRAND ISLAND
HAMILTON
30 WELLS 2,000 A
Amherst Reservoir
Mid-State Reservoir System
River
Lincoln
Creek
LEXINGTON
210 WELLS 17,000 A
KEARNEY
River
1100 WELLS 61,000 A
ADAMS
CLAY
60 WELLS 6,000 A
FILLMORE
SALINE
KEARNEY
HASTINGS
Plum Creek Reservoir
Tuskey
50 WELLS 2,000 A
Big
Sandy
40 WELLS 3,000 A
CENTRAL
NEBRASKA
P.P.&I.D.
30 WELLS 1,900 A
100 WELLS 3,500 A
140 WELLS 13,000 A
100 WELLS 7,500 A
PHELPS
HARLAN
FRANKLIN
WEBSTER
THAYER
JEFFERSON
Irrigation District
30 WELLS 2,500 A
30 WELLS 2,500 A
NUCKOLLS
10 WELLS 600 A
10 WELLS 400 A
Blue
FAIRBURY
ALMA
Creek
Republican
River
Harlan County Reservoir (850,000 A.F.)
10 WELLS 1,000 A
SUPERIOR
Bostwick Irrigation District


THURSTON
MADISON
STANTON
CUMING
10 WELLS 600 A
NORFOLK
Missouri
BURT
10 WELLS 400 A
PLATTE
COLFAX
60 WELLS 3,500 A
DODGE
110 WELLS 9,300 A
WASHINGTON
60 WELLS 3,000 A
Shell Creek Reservoir
Maple Creek
Platte River
FREMONT
COLUMBUS
SAUNDERS
10 WELLS 900 A.
40 WELLS 2,300 A
DOUGLAS
40 WELLS 1,500 A.
OMAHA
SARPY
Bellwood Reservoir
90 WELLS 8,000 A
POLK
BUTLER
YORK
SEWARD
LANCASTER
CASS
PLATTSMOUTH
River
150 WELLS 12,000 A
30 WELLS 2,000 A
LINCOLN
OTOE
NEBRASKA CITY
FILLMORE
SALINE
50 WELLS 2,000 A
40 WELLS 3,000 A
GAGE
JOHNSON
NEMAHA
THAYER
JEFFERSON
BEATRICE
PAWNEE
RICHARDSON
FAIRBURY
10 WELLS 1,000 A.
FALLS CITY

DEPARTMENT OF ROADS & IRRIGATION 1950

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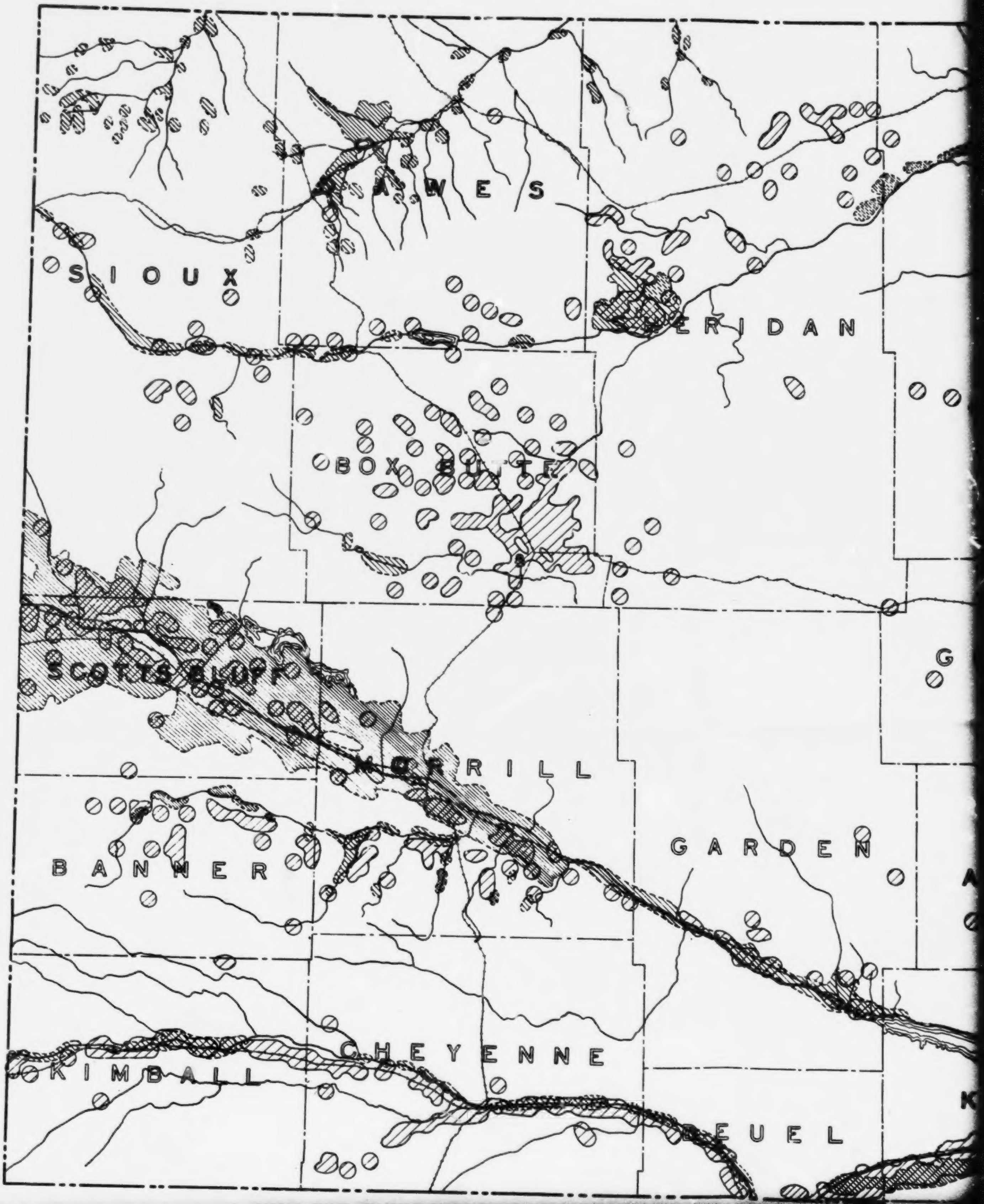
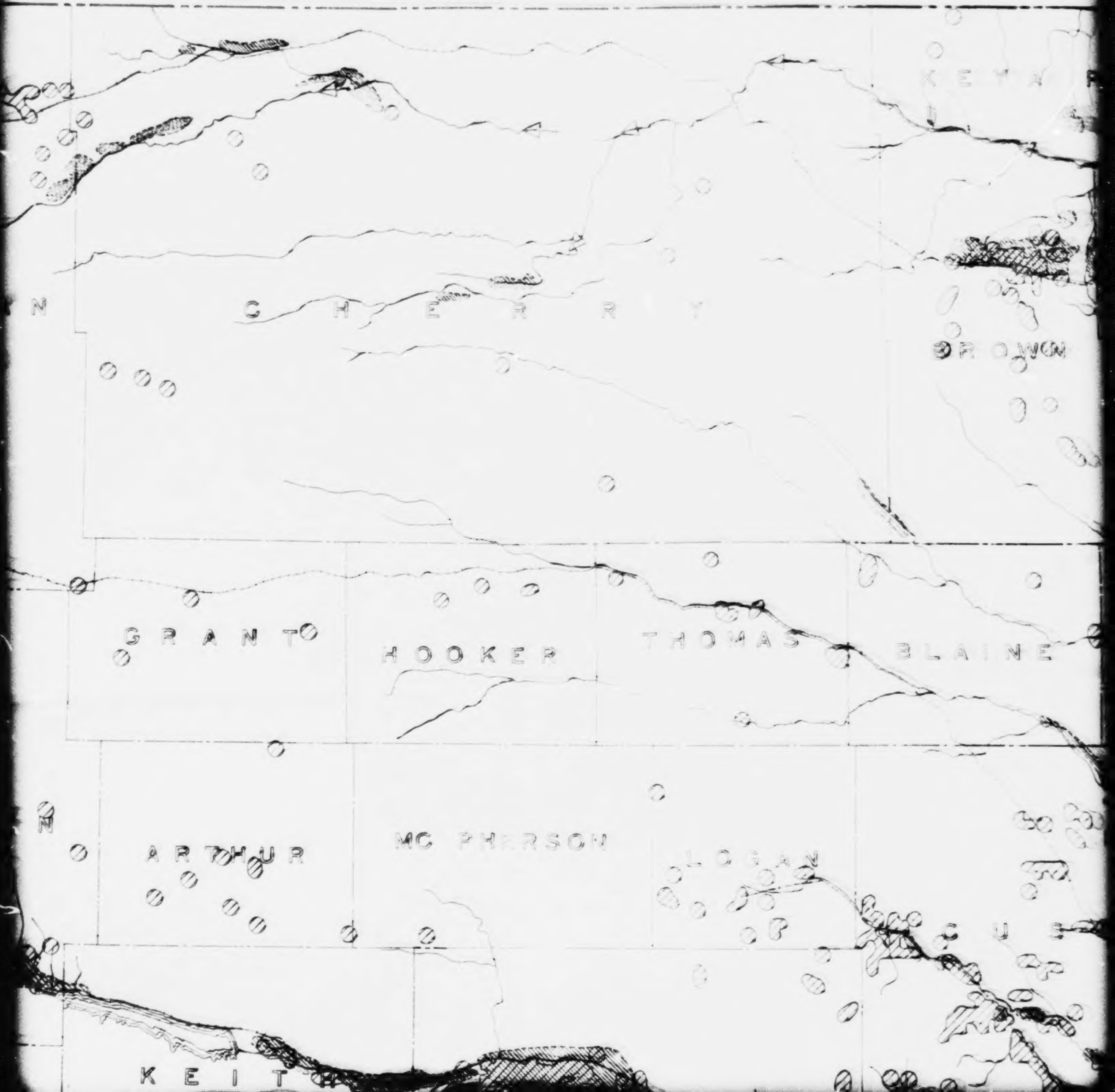
A


AWES
SIOUX
ERIDAN
BOX BUTTE
SCOTTS BLUFF
G
MORRILL
GARDEN
BANNER
A
CHEYENNE
KIMBALL
DEUEL
K

IRRIGATION MA

β JANUA


K E Y A P
N
CHERRY
BROWN
GRANT
HOOKER
THOMAS
BLAINE
N
ARTHUR
MC PHERSON
LOGAN
CUS
KEIT

ION MAP OF NEBRASKA

JANUARY 1, 1958

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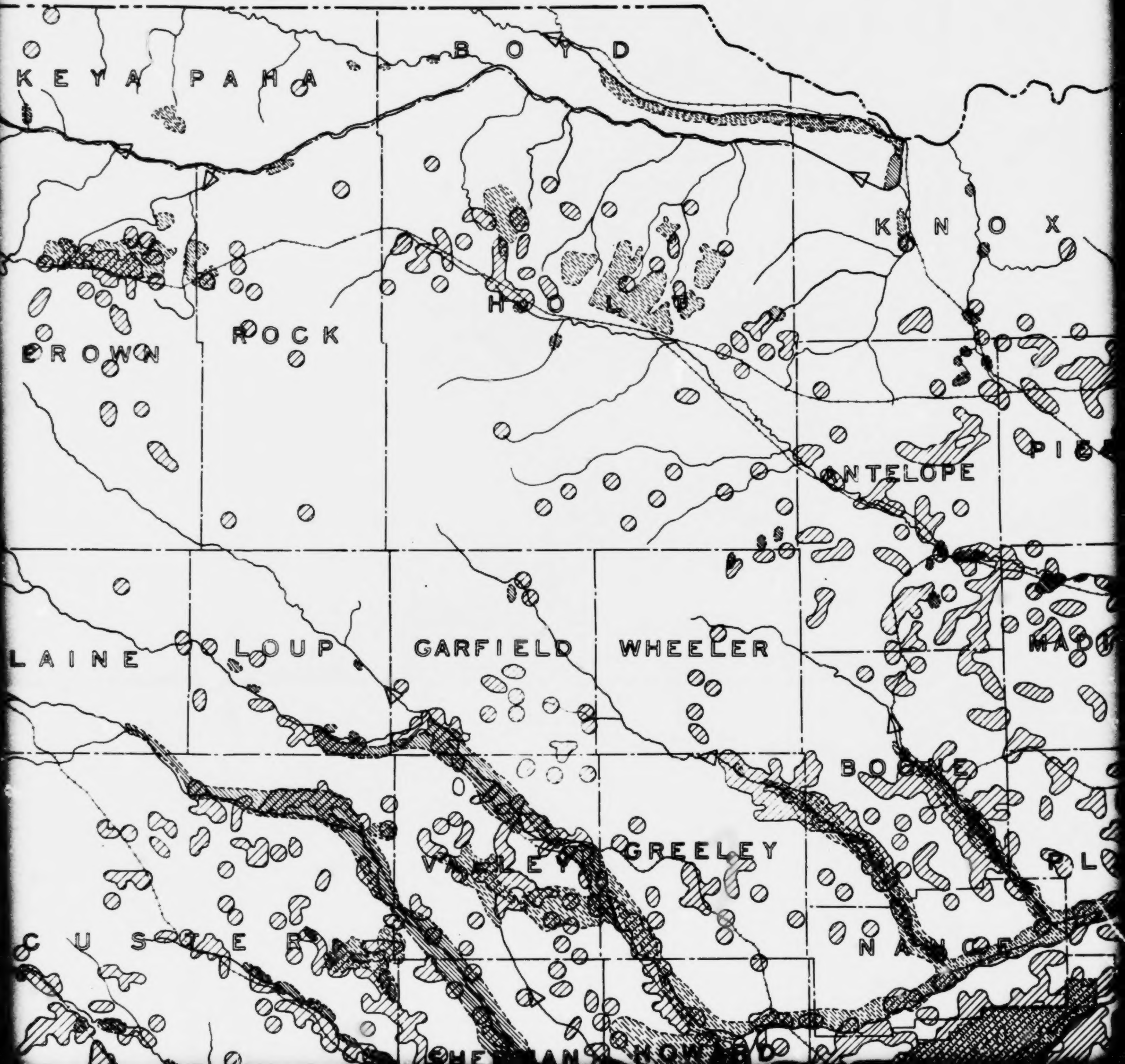

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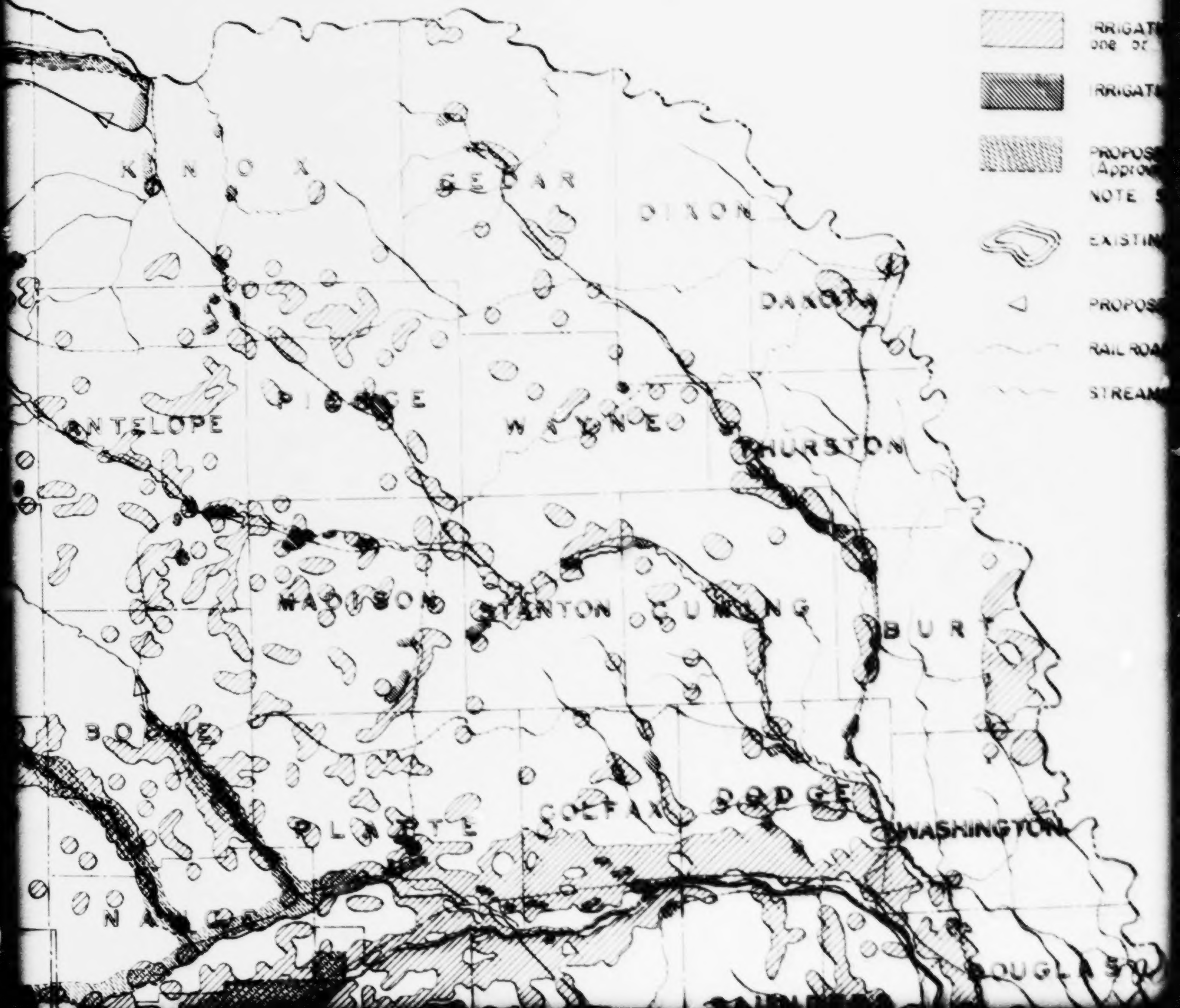
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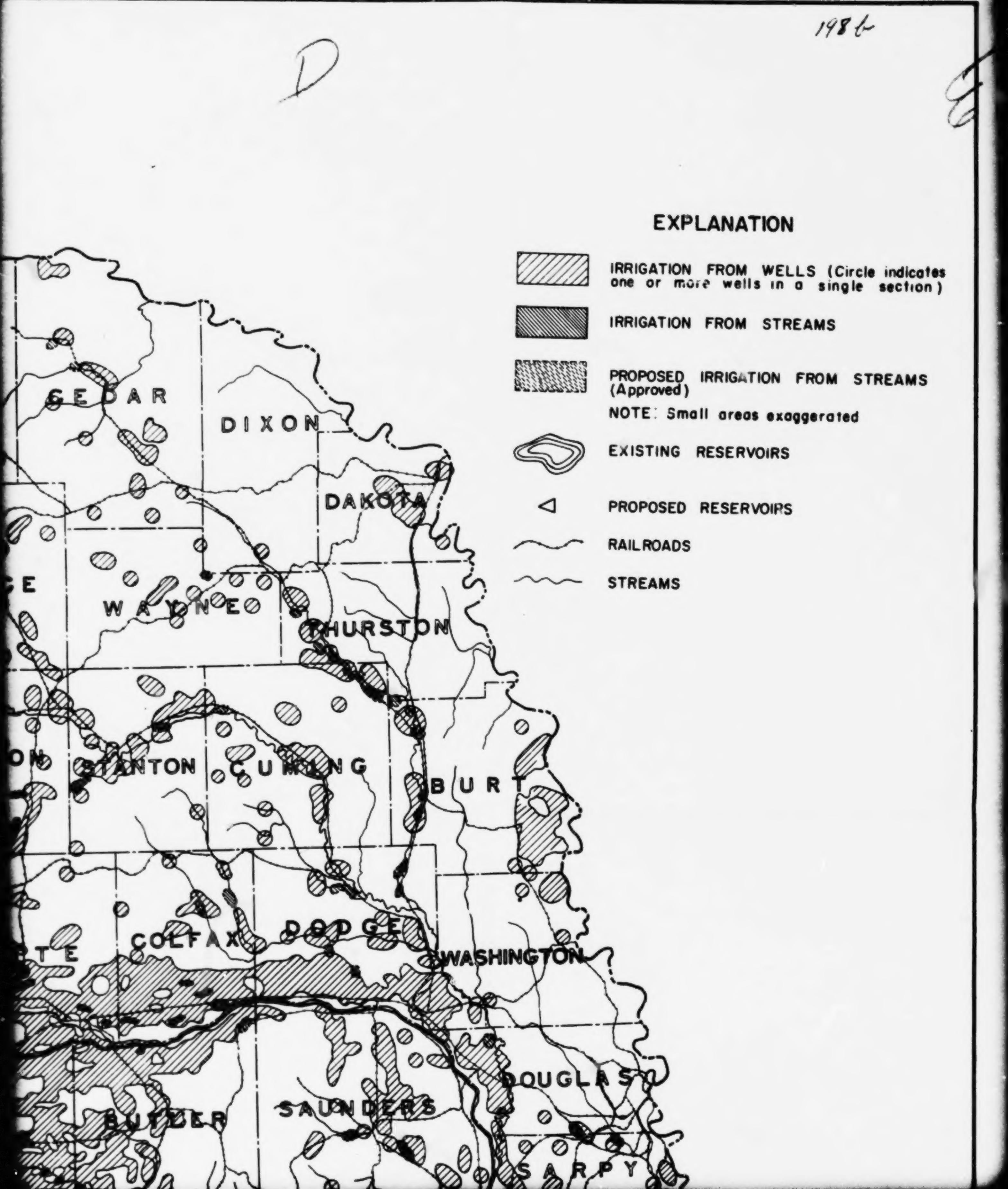
EXPLANATION
▨ IRRIGATION FROM WELLS (Circle indicates one or more wells in a single section)
▨ IRRIGATION FROM STREAMS
▨ PROPOSED IRRIGATION FROM STREAMS (Approved)
NOTE: Small areas exaggerated
EXISTING RESERVOIRS
◁ PROPOSED RESERVOIRS
RAILROADS
STREAMS
CEDAR
DIXON
DAKOTA
WAYNE
THURSTON
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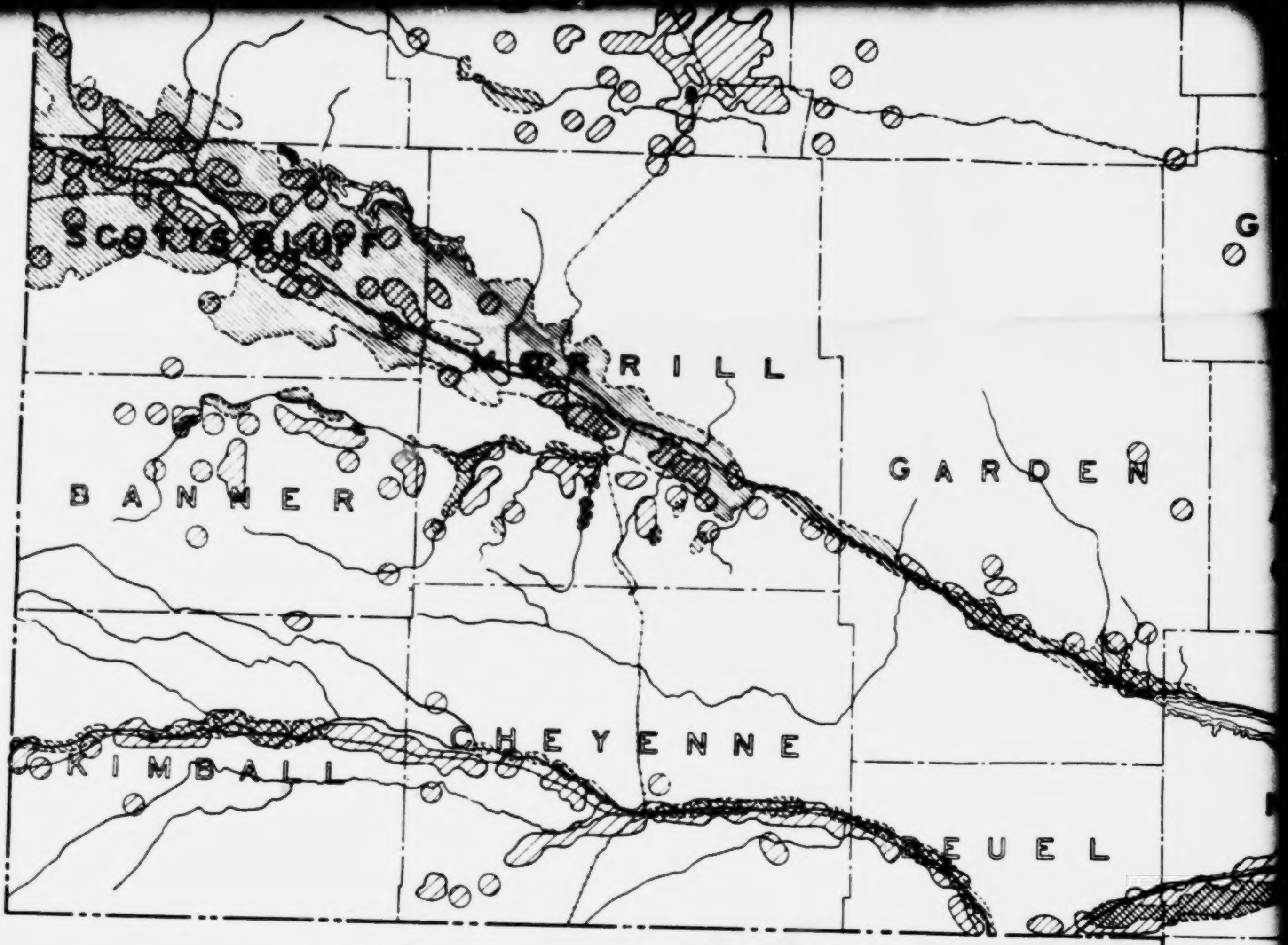
DODGE
WASHINGTON
DOUGLAS
SAUNDERS
BUTLER
SARPY



ACRES IRRIGATED IN NEBRASKA

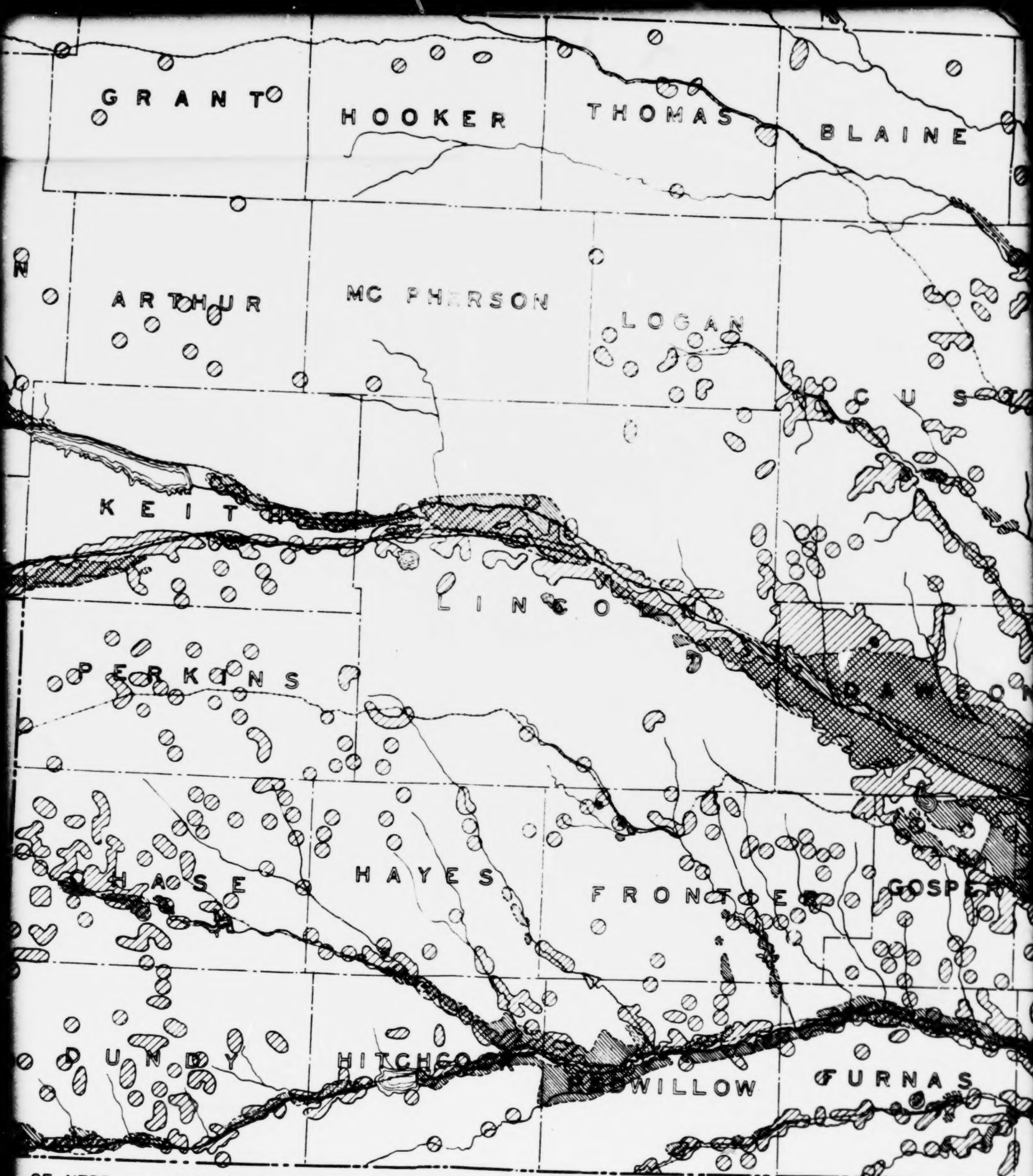
COUNTY	ACRES IRRIGATED FROM STREAMS	ACRES IRRIGATED FROM WELLS	NO. OF WELLS	COUNTY	ACRES IRRIGATED FROM STREAMS	ACRES IRRIGATED FROM WELLS	NO OF WELLS	COUNTY	ACRES IRRIGATED FROM STREAMS	ACRES IRRIGATED FROM WELLS	NO. OF WELLS
ADAMS	3,350	51,750	575	FRONTIER	2,100	7,100	71	NANCE	5,800	4,400	80
ANTELOPE	1,800	12,100	121	FURNAS	19,300	12,750	196	NEMAHA	1,750	200	2
ARTHUR	0	850	14	GAGE	4,550	8,600	101	NUCKOLLS	9,950	19,450	216
BANNER	1,500	3,100	48	GARDEN	17,900	4,500	56	OTOE	1,750	0	0
BLAINE	200	650	8	GARFIELD	5,550	3,600	48	PAWNEE	750	0	0
BOONE	7,950	20,250	253	GOSPER	10,500	10,350	122	PERKINS	0	5,600	43
BOX BUTTE	2,750	25,400	188	GRANT	0	350	4	PHELPS	80,350	40,300	448
BOYD	750	0	0	GREELEY	2,650	10,950	137	PIERCE	3,550	6,450	68
BROWN	1,200	7,350	98	HALL	50	131,400	2,190	PLATTE	6,000	24,700	353
BUFFALO	16,700	105,750	1627	HAMILTON	950	113,500	1,195	POLK	700	53,750	597
BURT	1,750	6,600	66	HARLAN	5,600	12,700	169	REDWILLOW	7,300	10,000	154
BUTLER	1,400	29,350	326	HAYES	4,750	4,850	46	RICHARDSON	2,000	100	1
CASS	1,100	1,700	17	HITCHCOCK	14,100	11,700	156	ROCK	1,100	1,100	14
CEDAR	1,750	2,700	30	HOLT	9,350	9,100	114	SALINE	8,800	16,550	207
CHASE	4,500	12,650	115	HOOKER	300	500	5	SARPY	1,450	4,950	55
CHERRY	14,100	1,100	11	HOWARD	3,950	14,700	226	SAUNDERS	3,300	11,650	106
CHEYENNE	3,350	11,200	149	JEFFERSON	2,850	6,200	65	SCOTTS BLUFF	191,550	9,500	146
CLAY	2,050	73,000	730	JOHNSON	1,350	1,300	12	SEWARD	7,200	27,100	285
COLFAX	2,900	18,200	280	KEARNEY	15,500	49,400	549	SHERIDAN	13,800	7,800	87
CUMING	1,950	3,100	44	KEITH	16,900	26,500	312	SHERMAN	10,500	9,300	124
CUSTER	12,600	35,550	395	KEYA PAHA	2,500	250	3	SIOUX	12,750	4,000	38
DAKOTA	50	2,000	19	KIMBALL	3,900	8,200	103	STANTON	1,550	4,800	64
DAWES	24,400	1,400	16	KNOX	2,300	1,300	16	THAYER	4,700	36,800	409
DAWSON	100,100	152,400	2,540	LANCASTER	6,300	5,500	73	THOMAS	400	900	12
DEUEL	5,300	8,400	121	LINCOLN	54,200	38,100	448	THURSTON	450	850	10
DIXON	1,850	200	2	LOGAN	800	2,500	21	VALLEY	26,250	11,800	124
DODGE	3,250	23,300	388	LOUP	5,800	1,700	24	WASHINGTON	50	1,200	13
DOUGLAS	1,150	3,650	73	MADISON	5,050	9,800	98	WAYNE	800	900	12
DUNDY	5,800	10,000	111	McPHERSON	0	50	1	WEBSTER	8,350	6,000	86
FILLMORE	950	63,400	604	MERRICK	700	75,250	1,505	WHEELER	150	950	11
FRANKLIN	11,200	16,400	205	MORRILL	117,200	6,100	76	YORK	3,750	92,150	1024
								TOTAL	*991,450	*1,705,550	22,107

PREPARED AND PUBLISHED BY: THE CONSERVATION AND SURVEY DIVISION, UNIV. OF NE

TOTAL ESTIMATED IRRIGATED AREA DURING 1957, 2,395,000 ACRES.

* (Part of area irrigated from stream source also irrigated from wells.)

8 O - 61 (Face p. 198) No. 2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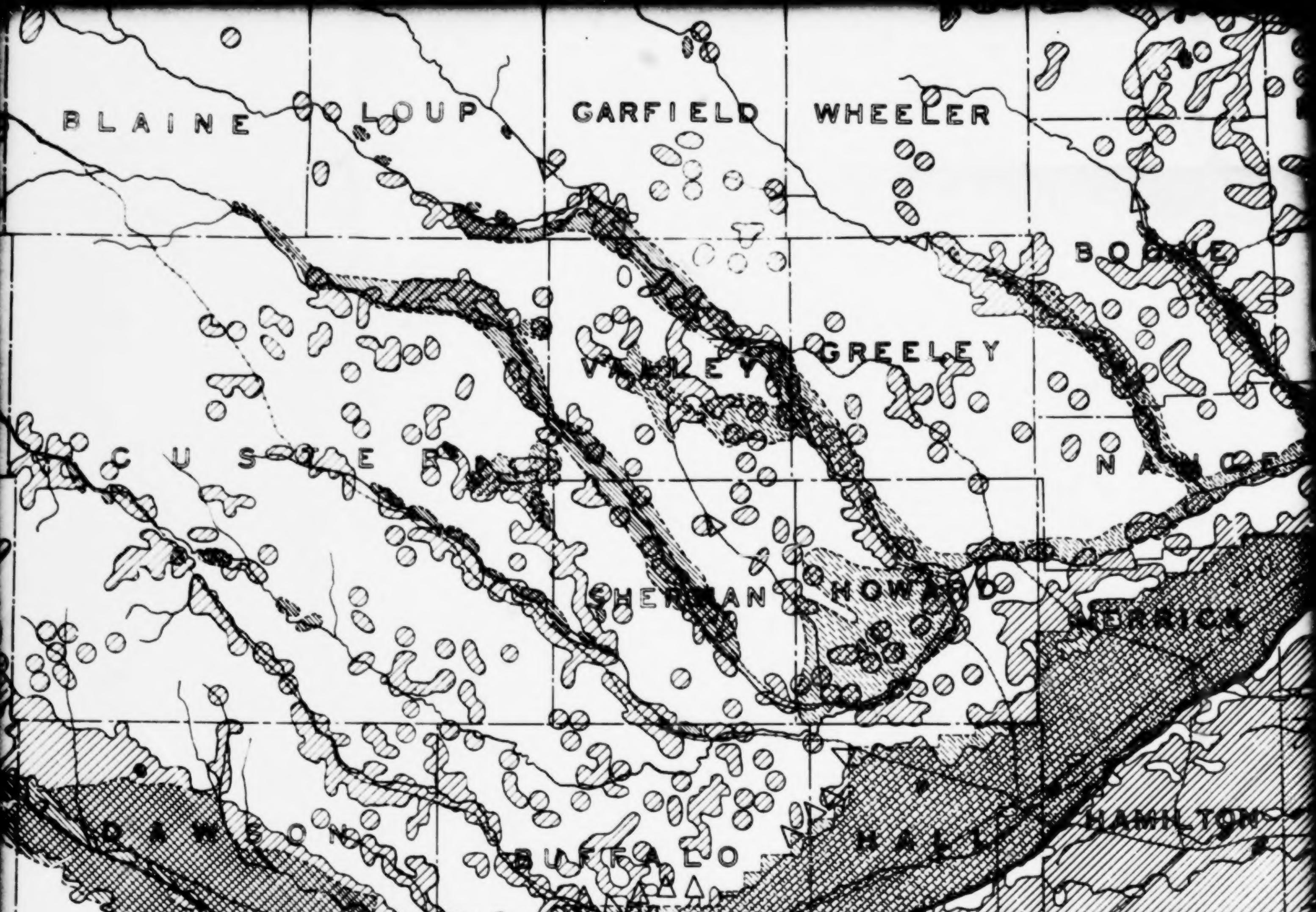
OF NEBR. IN COOPERATION WITH THE NEBRASKA DEPT. OF WATER RESOURCES; SOIL CONSERVATION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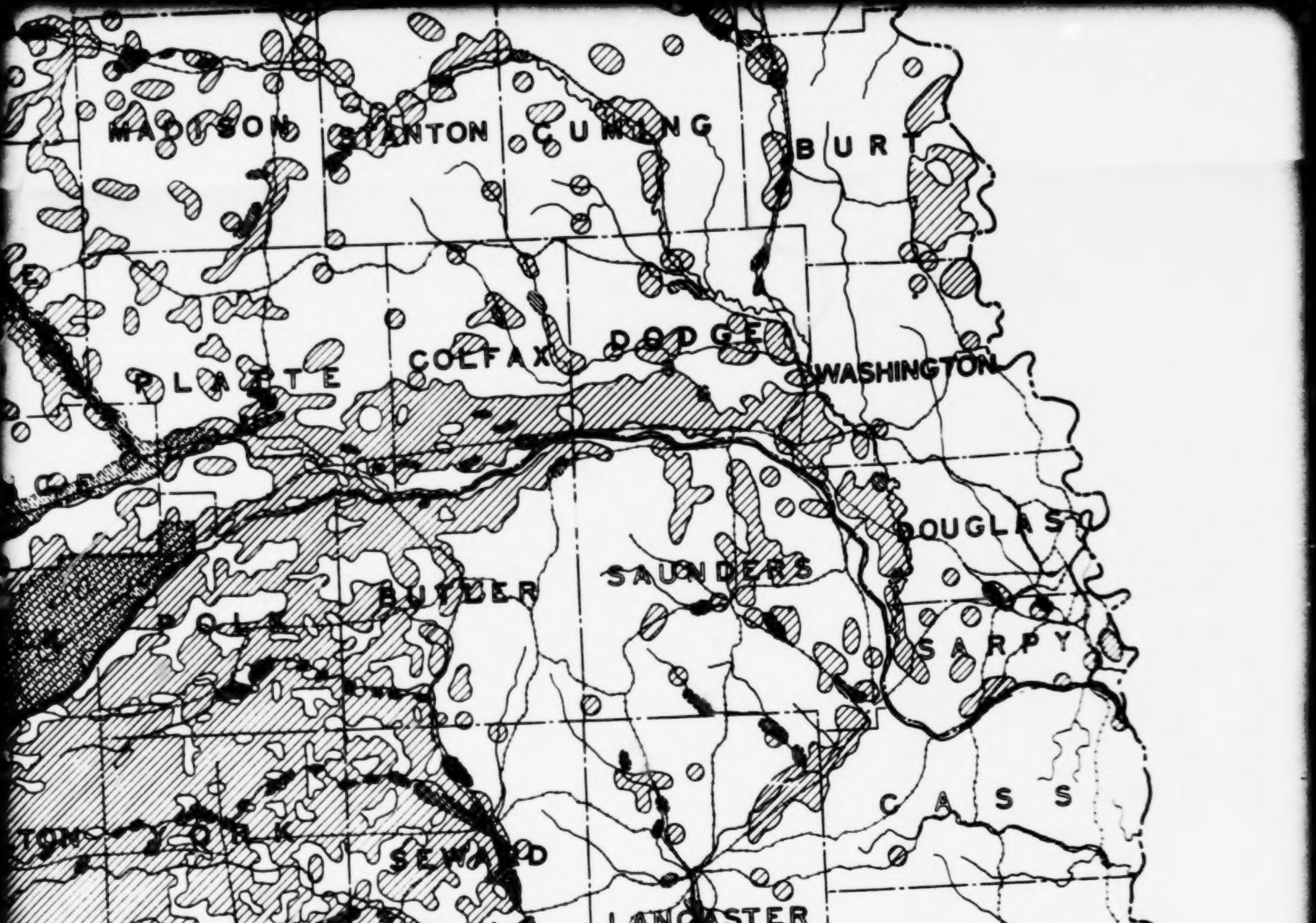
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THAYER
JEFFERSON
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EXTENSION SERVICE, UNIV. OF NEBR. AND GROUND WATER BRANCH, U.S. GEOLOGICAL SURVEY.

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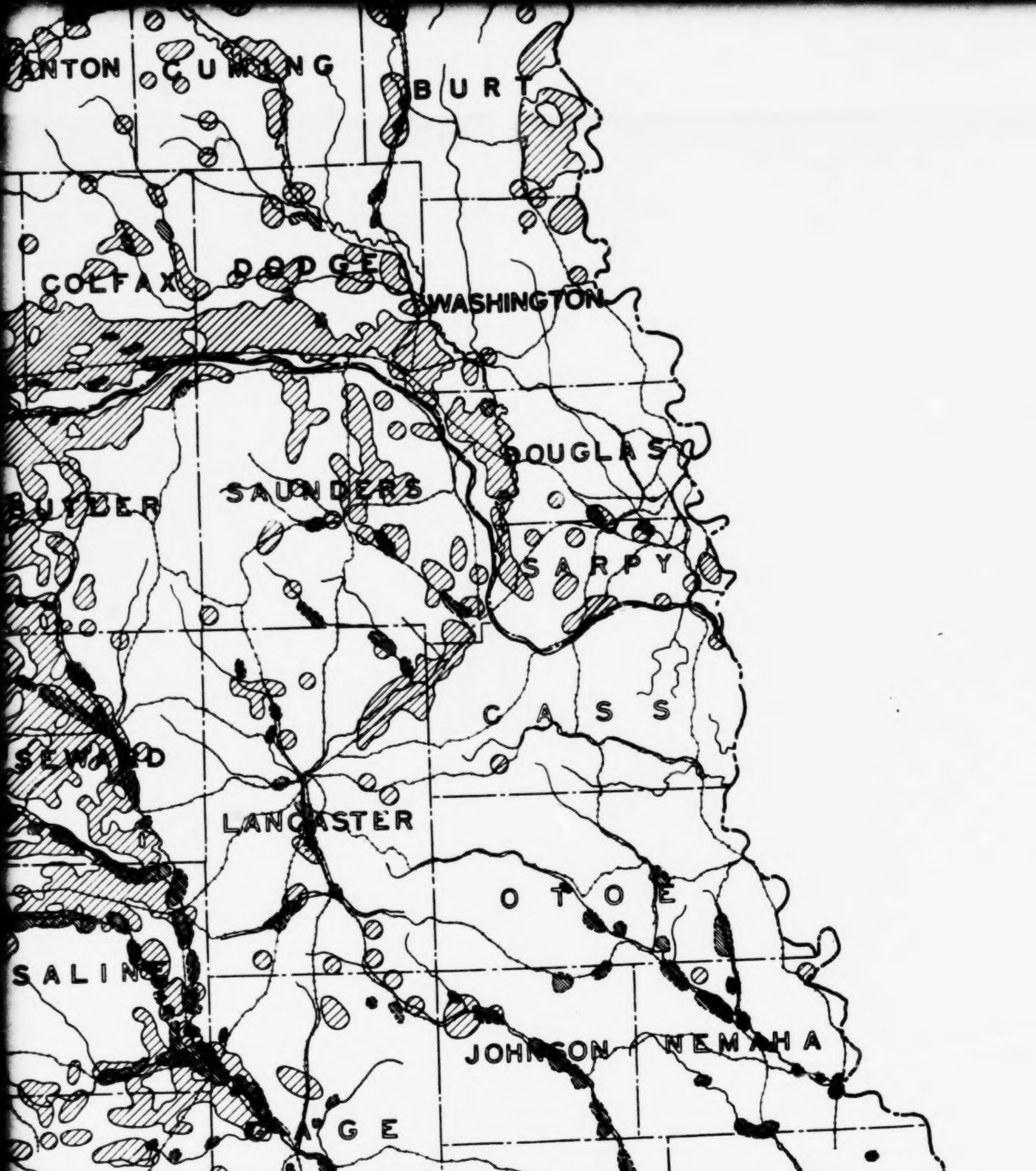
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JEFFERSON

F NEBR. AND GROUND WATER BRANCH, U.S. GEOLOGICAL SURVEY.

CARTOGRAPHY BY: V.J.HINES

Flood-control work of the Corps of Engineers on approved projects should be expedited by the appropriation of adequate funds for planning and construction. The flood prevention and watershed protection work of the Department of Agriculture needs to be accelerated. This can be done by placing more planning parties in the field. The 1959 Nebraska Legislature recognized the seriousness of this situation and appropriated funds to put two such planning parties in the field in 1959 and 1960 in addition to the one supplied by the Soil Conservation Service. The 1957 legislature enacted a Watershed Conservatory District Act, under which many districts have been organized and are able to assure the payment of local costs of watershed projects constructed under Public Law 566.

Nebraska has virtually no natural outdoor recreational facilities. Special attention should be given to the development of the recreational and fish and wildlife potentials in the planning of water resources projects. The benefits to these purposes should be taken into account in determining the economic feasibility of a water project. However, when irrigation is the primary purpose of the project, the use of the water for recreation and for fish and wildlife purposes should remain incidental to the primary use.

Although we have not been faced with problems associated with reserved lands, as have Oregon and Nevada, we are becoming more and more concerned with the problems involved in Federal-State relations in the field of water rights. We feel that the Congress should enact clear-cut legislation on the subject. Inasmuch as Nebraska has adequate water laws under which individuals, corporate bodies, and agencies of the United States have acquired water rights and operated projects successfully, we see no reason why Congress should not remove the cloud which now hangs over all water right matters as a result of the *Pelton Dam* and *Hawthorne* cases.

Of immediate concern to us at this time are two problems resulting from the ability of agencies of the United States to initiate proceedings relating to water rights in the Federal courts. Two suits now pending in the Federal district court, one for 5 years, have made it impossible for this department to properly carry out its administrative duties in one of the major river basins of the State, resulting in a chaotic condition. Had the cases been handled in the State courts, they would have been decided quickly and there would have been no question as to administrative authority.

Nebraska law provides that the first in time is first in right and that continuous beneficial use of water should be made in order to retain the right to use. We believe this to be a sound principle and believe that it should not be changed.

Nebraska is a party to two interstate compacts, is negotiating another at this time, and it is anticipated that we shall shortly be negotiating another, depending upon the granting of consent by the Congress. We subscribe to this method of settling or avoiding interstate water controversies. We also endorse the principle of accomplishing coordination and cooperation of the States and the United States through basin interagency committees.

The Water Resources Division of the U.S. Geological Survey has for years done an outstandingly fine job, generally in cooperation with the States, in gathering basic water supply data. The need for the continuation of and expansion of this data collection program becomes more important as our water use increases. Adequate funds should be appropriated for the continuation of the cooperative program and for the operation and maintenance of interstate compact and Federal type stations by the Geological Survey.

The improvement of the Nation's rivers to increase their navigability should be encouraged, provided that such use does not interfere with the use of water for beneficial consumptive uses.

Very truly yours,

Dan S. Jones, Jr.,
Director of Water Resources.

LIBERTY, NEBR., *February 26, 1960.*

Senator ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: On behalf of the Nebraska Association of Soil & Water Conservation Districts, I am very pleased to forward the following information on the water resources of Nebraska for the review of your committee. I regret that I was unable to present this material to your committee. Originally, I had made plans to submit this report at the hearings in Topeka, Kans. However, later I was informed that only Kansas representatives would be given an opportunity to make this presentation.

The State of Nebraska has widely diverse soil and water management problems. Since we are primarily an agricultural State, the economy of our State is dependent to a large percent on how well we manage our two basic natural resources—soil and water.

In the eastern part of the State, the major problems are concerned chiefly with the control of surface runoff water to (*a*) prevent soil losses from pastures and cropland; (*b*) reduce sedimentation of downstream area (channels, reservoirs, etc.); (*c*) reduce the damages caused by flooding; and (*d*) manage those runoff waters for municipal, industrial, recreational, and wildlife purposes. Technical assistance (Soil Conservation Service technicians) and ACP cost-sharing available in our soil and water conservation districts have done much to solve the above-named problems. However, the conservation program is just getting a good start in Nebraska. The advent of the small watershed program, Public Law 566, gives promise of assisting the local soil and water conservation districts in solving some of the above-named problems. The watershed program appears to hold considerable promise in such areas as the Blue River Basin, Nemaha Valley, Papio Creek, Elkhorn Valley, etc. However, a "bottleneck" in the watershed program has developed in watershed planning. Additional assistance in planning is needed. Also, certain Federal planning criteria is making it impossible for certain needed projects to be eligible for Public Law 566 assistance.

Toward the central part of the State, however, lower average rainfall and more frequent drought periods make it necessary to consider, in addition to those prevalent in the eastern part of the State, the necessity of water conservation on cropland and rangeland. It is in this area considerable deep well and ditch irrigation has developed. Irrigation is used in many areas as a supplement to the rainfall. Proper irrigation water management and the conservation (wise and efficient utilization) of our underground water resources is a problem. We are becoming increasingly concerned in a few areas of the apparent depletion of our underground water resource. The sandhills of Nebraska are located in this area. Proper range management is important here to conserve moisture, increase soil cover, and prevent wind erosion.

The problems enumerated above increase in intensity toward the western end of the State. Recurring series of drought years tend to disrupt the economy of that area by reducing range feed and stockwater. Also, crop failures cause distress to farmers, ranchers, and townspeople. Moisture conservation is becoming increasingly important in Nebraska as you travel west. Terraces, contour strip cropping, stubble mulch, range management, irrigation bench leveling, lined irrigation ditches, and other irrigation practices are being applied at an accelerated rate to conserve all available moisture.

The recently enacted Great Plains conservation program has already proved to be a practical approach to many of the soil-moisture problems in central and western Nebraska. This program achieves planned conservation on an entire farm or ranch unit. Through this program, we believe that it will be possible to stabilize not only the soil and water resources, but also the economy of the area through needed land conversion. Many acres of marginal cropland are being reseeded and converted to rangeland.

Protection of water, soil, and human resources is of high priority in the State, and new and improved technical methods are needed for sustained productive farming and ranching suitable to the various conditions within the State of Nebraska. The efficiency of conversion of water and of sunlight energy into food and fiber on our dryland farms and on our rangelands is much lower than it need be. Research has recently indicated it may be possible to greatly increase the efficiency of water use on agricultural lands. If so, the water saved could amount to many times the water now stored within existing reservoirs within the State. The costs of doing such research would be much less than the cost for major storage and control facilities. For this reason, we believe that agricultural research devoted to improving the efficiency of water use and the conservation of our soils is of prime importance to the economy of the State and of the entire country.

Research funds are needed to provide knowledge and methodology for achieving efficient water and soil resource utilization. The following are resolutions on soil and water research that were adopted by supervisors at the 19th Annual Convention of the Nebraska Association of Soil and Water Conservation Districts, which was held in Scottsbluff, Nebr., on October 4, 5, and 6, 1959:

1. Conservation of soil moisture by reducing evaporation and increasing intake.
2. Depletion and recharge of groundwater resources.
3. Improved methods for the control of water erosion, especially in eastern Nebraska.
4. Improved methods for control of wind erosion, especially in western Nebraska.
5. Evaluation of effectiveness of the watershed approach in conservation of soil and water, and in reducing flood hazards.
6. Land shaping practices and structures for soil and water conservation, such as bench leveling for irrigation, conservation benches, terraces (design and spacing), earth-filled dams, and gully stabilization.
7. Management of ranges and pastures to give maximum sustained production and to control wind and water erosion.
8. Development of new grass and forage varieties for use in conservation systems and to meet specific conservation needs.
9. The nature of drought resistance and the development of new crops or crop varieties, especially for central and western Nebraska.
10. Efficient utilization of irrigation water, including methods of application, drainage, prevention of the development of saline and alkali conditions, cropping systems, and fertilization practices.
11. Irrigation well development in relation to different kinds of water bearing formations.
12. Quality of water for irrigation purposes and the reclamation of saline and alkali soils.
13. Field windbreaks for modifying the environment and influencing crop yields, including an evaluation of artificial barriers, windbreak design, the development of various species and improved tree varieties for this use, establishment, management and pest control.
14. Development of equipment to adequately farm land which has been terraced, benched, or otherwise managed to control wind and water erosion.
15. The role of micro-organisms in soil structure, organic matter decomposition, and plant nutrient availability and techniques involved in more effective utilization of micro-organisms
16. Evaluation of costs and benefits to farmer, consumers, and governmental subdivisions in development and application of each conservation practice.

We feel that, if research is to do its share in providing means of more efficient soil and water resource conservation and utilization, very substantial increases in funds for facilities, personnel, and research operations are needed. Beyond increasing research funds in the State at such locations as Lincoln, Mitchell, North Platte, and Hastings, the moisture conservation research laboratory recommended by the Great Plains Council is needed badly to provide the farmers of the 10 Great Plains States the knowledge and methodology necessary to increase the efficiency of soil-stored water.

Last year, the Secretary of Agriculture held a series of hearings over the Nation to determine the needs for increased facilities to do research on soil and water problems. The summary of these studies now has been made available in a document known as Senate Document No. 59 of the last session of the 86th Congress and is entitled "Facility Needs and Soil and Water Conservation Research." This document, as printed, provides for the establishment of adequate facilities to do research on these important problems. In view of the increasing importance of wisely conserving our water resources, as well as our soil resources, we recommend that Senate Document No. 59 and the request of the Association of Land Grant Colleges for soil and water conservation research funds should be given full consideration in the forthcoming Congress.

We members of the Soil Conservation District Association of Nebraska give our full support to the implementation of research in soil and water conservation and submit this combined opinion of the representatives of the association as a part of our presentation at the public hearing on water resources.

Yours truly,

EVERETT BARR, *Secretary and Director.*

FEBRUARY 26, 1960.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR AND MEMBERS OF THE SELECT COMMITTEE: The Nebraska Soil and Water Conservation Committee has designated me to present the opinion and attitude of the official agency in Nebraska in the field of soil and water conservation to your committee. The State soil and water conservation committee is composed of five elected soil and water conservation district supervisors, the director of the State department of water resources, the dean of the college of agriculture, the associate director of agricultural extension, the director of the conservation and survey division of the university and two additional members appointed by the Governor to represent municipal and irrigation interests. Thus this committee has a broad interest and knowledge in the field of water and its utilization. We wish to express our interest in the work of the select committee and our appreciation of this opportunity to present our viewpoint.

Nebraska has been plagued through the years with great variability in amounts of precipitation and the agricultural production has suffered during prolonged periods of drought. This condition has been alleviated greatly through the development of the agricultural use of both surface and ground water to the degree that 2,600,000 acres of land in the State are now irrigated. Almost two-thirds of Nebraska's irrigated acreage is served from ground water sources which have been developed with private investment. This investment amounts to some $400 million or more.

The peak installation of irrigation wells in the State occurred during 1956 and almost as many were installed in 1957. Therefore the full impact of this increased ground water use has not been felt because of the lesser need for supplemental water during the past 3 years. It appears that the ground water in some local areas of the State may be overdeveloped and that continued extensive use of ground water may result in some reduction in streamflows which will present problems in the future.

It is expected that the competition for water in Nebraska will increase in the future to the degree that there may be some serious problems and need for adjustment. At the present time, Nebraska has legislation which permits the establishment of pump irrigation districts which can control ground water use on a local level and a priority of ground water use with domestic first, agricultural second, and industrial third is now established by law. Whether these controls will be completely effective in the future remains to be seen, but there is a growing understanding of the problems by the people of the State.

It is anticipated that there will be a future expansion of industrial development in Nebraska, especially along lines that are related to agriculture and the industrial requirements for water are expected to increase greatly as will the domestic needs. There is a need for the development of a more efficient use of water and efforts should be made to reduce the deterioration of water quality, so far as nonconsumptive uses are concerned. Artificial ground water recharge may be essential in many areas to maintain ground water levels for effective use in the future. This is being accomplished to some degree in some sections of Nebraska through the application of surface water or storage water for irrigation use. There is also a good potential that watershed development and protection will contribute to better infiltration and less serious water losses. Every effort should be made to reduce nonproductive losses of water through evaporation in the Great Plains area, and methods should be developed to permit the conversion of poor quality water to usable quality water at a more reasonable cost.

The present efficiency of agriculture in this Nation that permits an abundance of food for all of the Nation from the labors of a small percent of our population, thus freeing others for the development of industry, should not be discouraged even in the fact of agricultural surpluses, because it is the real source of our strength. Also, the agricultural use of water and the real national need for this use to stabilize agricultural production in areas of great climatic variability should be fully recognized by the Nation in order to eliminate the necessity for extensive and expensive public relief for some large segments of the country during periods of prolonged drought.

Yours very truly,

NEBRASKA SOIL AND WATER CONSERVATION
COMMITTEE,
By E. C. REED,
Ex Officio Member;
Director, Conservation and Survey Division, University of Nebraska.

NEVADA

THE STATE OF NEVADA,
EXECUTIVE CHAMBER,
Carson City, September 23, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Senate Office Building, Washington 25, D.C.

DEAR SENATOR KERR: I am writing you in reference to your letter to me dated June 23, 1959, calling my attention to Senate Resolution 48, adopted April 20, 1959, and which provides for the establishment of a Senate Select Committee on Natural Resources. You further advised that the committee was obtaining basic data on the Nation's water supply and information on proposed Federal plans and programs from both the Federal Government and the States. You requested that the committee be furnished with a statement as to the water problems of our State, present and anticipated.

I turned your correspondence over to Mr. Hugh Shamberger, director of the Nevada Department of Conservation and Natural Resources, and Mr. Shamberger has prepared a nine-page report which I hope will be of interest to the committee. I have sent you six copies of this report.

I am advised by Mr. Shamberger that he has been working with the Bureau of Reclamation in preparing estimates as to the non-Federal development of irrigated lands between now and 1980, and also between 1980 and the year 2000.

I want to congratulate you on being the sponsor of this important legislation, and you may be assured that the facilities of our State government will be available to assist your staff in any way possible.

Sincerely yours,

GRANT SAWYER, *Governor.*

PRESENT AND ANTICIPATED, WATER PROBLEMS, STATE OF NEVADA [1]

(By Hugh A. Shamberger, director, department of conservation and natural resources)

Area

Nevada is the seventh largest State in the Union with a total area of 110,540 square miles, or 70,745,000 acres. Of this area, approximately 5,300 square miles, or 4.8 percent, lies within the Snake River drainage which is tributary to the Columbia River and the Pacific Ocean. About 12,000 square miles, or 10.9 percent, of the State lies within the Colorado River drainage. The balance, or approximately 93,000 square miles, or 84.3 percent, lies within the Great Basin where the drainage is all inland.

Aridity

Nevada is the most arid of the States with an estimated average annual precipitation of about 8.9 inches. On about 18 percent of the area of the State the annual precipitation averages less than 5 inches; on 42 percent of the area, less than 8 inches; and on 90 percent the precipitation is less than 15 inches. It is from the remaining 10 percent of the State's area, where the precipitation exceeds 15 inches, principally in the form of snow, that we receive the bulk of the water supply originated within the State.

Recent geological history

In the relatively recent geological history of Nevada, there have been periods when the rainfall was comparatively heavy, perhaps as much as three or four times greater than the average for the past several centuries. During these periods of heavy rainfall, the most recent of which occurred 5,000 years or more ago, many of the enclosed valleys within the State contained lakes. It was during this period that Lake Lahontan had a surface area of about 8,450 square miles and covered a large part of western Nevada. Pyramid and Walker Lakes are mere remnants of this old lake. Other lakes, some of them considerably older, once occupied areas around Elko, Panaca, Moapa, and Las Vegas.

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[1] Prepared September 1959 at request of Senator Robert S. Kerr, chairman, Select Committee on National Water Resources, in connection with S. Res. 48, 1959.

Surface runoff

It is estimated that the average annual streamflow in Nevada is about 3,150,000 acre-feet. About 66 percent of this amount, or 2,070,000 acre-feet, is carried by the four major streams—namely, the Walker, Carson, and Truckee Rivers—originating in the high Sierra Nevada Mountains in California and the Humboldt River. The three rivers first mentioned all flow eastward, the Truckee River terminus being Pyramid Lake, the Carson River being the Carson Sink, and the Walker River emptying into Walker Lake. With present upstream storage and use, water now reaching these terminal points has been greatly reduced from virgin conditions. The Humboldt River originates in northeastern Nevada near Wells and flows westward, emptying into Humboldt Sink. Only in years of above normal runoff does much water, other than drainage from the irrigated lands in Lovelock Valley, reach the Sink.

A tabulation of the approximate average flows follows:

Source	Average flow acre-feet	Tributary to—	Basin
Truckee River	560,000	Pyramid Lake	Great Basin.
Carson River	440,000	Carson Sink	Do.
Walker River	450,000	Walker Lake	Do.
Humboldt River	600,000	Humboldt Sink	Do.
Little Humboldt Sink	70,000	Humboldt River	Do.
Quinn River	30,000	Black Rock Desert.	Do.
Other minor streams	148,000		Do.
Salmon Falls Creek	120,000	Snake River	Columbia River.
Bruneau River	200,000	do	Do.
Goose Creek	34,000	do	Do.
Owyhee River	110,000	do	Do.
West Fork Owyhee River	200,000	do	Do.
Virgin River	200,000	Lake Mead	Colorado River.
Muddy River	33,000	do	Do.
Meadow Valley Wash	5,000	do	Do.
Total	3,150,000		

Of this amount, approximately 180,000 acre-feet is presently leaving the State from the Colorado River drainage and about 550,000 acre-feet from the Columbia River drainage in Nevada.

Stream gaging stations

In Nevada and its adjacent drainage basins, 73 stream gaging stations, 9 reservoir gaging stations, and 2 lake gaging stations are now operated. These are divided as follows:

Walker River basin: 15 stream, 2 reservoir, and 1 lake.
Carson River basin: 6 stream.
Truckee River basin: 16 stream, 2 reservoir, and 1 lake.
Quinn River basin: 3 stream.
Owyhee River Basin: 3 stream and 1 reservoir.
Salmon River basin: 2 stream.
Humboldt River basin: 20 stream and 1 reservoir.
Colorado River basin: 8 stream and 3 reservoir.

Ground water program

A cooperative ground water program with the U.S. Geological Survey was started in 1945. Since that time a number of ground water reports have been printed as State of Nevada Water Resources bulletins. These reports, 12 in number, cover 19 valleys. In addition, one report was published as a water supply paper. A number of duplicated reports and typewritten reports have been prepared.

A supplemental report to the 1948 reports of Las Vegas Valley will be printed soon. In addition, ground water studies in Kings River Valley, Crescent Valley, and Winnemucca Lake will be available during fiscal year 1960.

A statewide network of observation wells is being maintained, consisting of some 250 wells.

Present problems

As the result of the rapidly increasing population in Nevada, which is constantly emphasizing the need for increased water supplies, many problems are becoming evident; problems which should be studied immediately. Some of the problems are herewith set forth:

1. The need for more basic data. This includes—
    - Precipitation records.
    - Topographic mappings.
    - Stream gaging.
    - Ground water studies.
    - Evapo-transpiration information.
    - Observation wells.
    - Evaporation data.
2. A study as to the salvage of water used by nonbeneficial phreatophytes. It has been esti-

mated that in Nevada about 2,800,000 acres are covered with phreatophytes consuming about 1,500,000 acre-feet of water.

3. A stepped-up program for the determination of our ground water resources.

4. Statewide survey as to availability of small reservoirs that could be used to increase water supply.

5. An evaluation of the effectiveness of the present irrigation practices and facilities and the preparation of recommendation for improvement.

6. Investigate upstream water storage opportunities and analyze and prepare information to help solve the problems of highly variable annual and seasonal streamflow, to relieve problems of floodwater and sediment damage and provide for fish and wildlife development.

7. Conduct investigation, prepare and analyze information on needs and possibilities for drainage in areas where high water table conditions severely limit effective use of soil and water resources.

8. Expedite the study of watershed protection and flood prevention needs.

9. Studies on prevention and correction of stream, reservoir, and lake pollution.

10. Studies on utilization of recreational potential of State's water supplies.

WHAT THE STATE OF NEVADA IS PRESENTLY DOING

Department of conservation and natural resources

The department of conservation and natural resources was created by the 1957 legislature under a law NRS 232, which became effective July 1. Under the department there are four divisions, namely:

Division of water resources, headed by the State engineer.

Division of forestry, headed by the State forester.

Division of oil and gas, headed by the chairman of the oil and gas conservation commission.

Division of State lands, headed by the State land register.

In setting up the new department, the legislature provided that the director shall:

1. Formulate the policy of the department and the various divisions thereof:

2. Coordinate the activities of the various divisions thereof;

3. From time to time adopt, amend, and rescind such rules and regulations as he may deem necessary for the operation of the department;

4. Plan such studies and investigations as he may deem appropriate and carry out the same in conjunction with the various divisions; and

5. Coordinate all studies in the State concerned with the supply, development, use, and conservation of water.

The act further provides that the director, upon request and when the facilities of his department will permit, assist the Governor and other State departments or agencies in connection with technical matters pertaining to interstate waters and other matters related to the development or conservation of natural resources. It is under this provision that the department is carrying on the engineering studies in connection with the Arizona-California suit over the waters of the Colorado River, in which suit Nevada is an intervenor.

Primarily, the department will have the responsibility for developing an integrated State program for the conservation and development of natural resources; to negotiate with the Federal Government and State agencies in the natural resources and conservation fields; develop constructive programs for conservation, use, and orderly development of the resources of the State, including but not restricted to soils, water, forests, and oil.

The legislature no doubt felt that the consolidation of natural-resources activities into a single unified department under unified guidance and control would be beneficial as it would permit development of a long-range, integrated, and correlated program. It is entirely possible that the legislature will in future years, designate other existing State agencies as divisions within the department as the need for such further consolidation becomes manifest.

The legislature left the door open for the department to develop programs, local and statewide, aimed toward the development and conservation of our natural resources.

This department is attempting to initiate additional programs relating to the conservation, development, and proper use of the natural resources of the State.

Humboldt River research study

Very broadly, this project is concerned with developing data, techniques, methods, and procedures which may be usable and valuable in measuring the land and water resources of Humboldt River and in developing programs for their effective utilization. The use of the findings from this project in other similar situations in the State, or elsewhere, would be an added benefit.

Briefly, the first objective of this project is to find out how much water is being used and lost in the Winnemucca section of Humboldt River. This involves an accurate determination of the total quantity of water entering the area, the total measurable quantity leaving the area through surface and subsurface flows, and the uses and losses within the area.

The Winnemucca section was chosen as the site for the initiation of these studies for several reasons. The area is not too large. The Humboldt River bottom extends in a narrow ribbon from Rose Creek on the west to Comus on the east. There are about 18,000 to 20,000 acres of bottom land of which some 16,000 acres have water rights and are irrigated. In addition, there are several thousand acres of irrigable benchland which are situated a few feet above the river bottom. The airline distance from Rose Creek to Comus is approximately 35 miles. The mileage following the meandering stream channel probably is at least double that distance.

As rapidly as time and facilities will permit, the studies will be expanded to the upstream segments of the river, and eventually the entire Humboldt River drainage basin will be covered. Evaporation stations will be established at several points this year, and arrangements are being made with the U.S. Weather Bureau to install instruments at Weather Bureau and CAA stations to obtain meteorological data not presently measured at these stations. Wells to measure water-table fluctuations are planned. Later, tanks to measure evapo-transpiration of meadow plants will be installed. Geological and geophysical studies will be started on upstream areas as soon as the studies of the Winnemucca area have been completed.

The Winnemucca studies are outlined on a schedule of about 5 years. If everything should be operating satisfactorily at the end of this first period, some phases of these studies might be continued beyond this scheduled date. No time schedule has been worked out for the completion of the study of the entire river system, but much preliminary work should be accomplished on much of the upstream area within the 5-year period.

The agencies taking an active part in these studies are division of water resources, State bureau of mines, Agricultural Research Service, U.S. Geological Survey, Bureau of Reclamation, and Weather Bureau. The State department of conservation and natural resources will coordinate the program.

An important factor in any program such as this is the outlook for the use of the material developed in the study in practical applications. Economic factors will be considered in a series of continuing studies by the economic section of the Max C. Fleischmann College of Agriculture and Experiment Station.

Of more than passing interest in this area is the mosquito problem. A study of insect pests has been initiated and will be carried forward by the Branch of Entomology of the Agricultural Research Service.

The Soil Conservation Service cooperates with the Sonoma Soil Conservation District and has a direct interest in this program. Data obtained from these studies may be applicable in arriving at solutions to practical problems encountered in planning developments for the area. The SCS will accelerate its program of soil surveys and topographic mapping, and will make an inventory of phreatophytic vegetation in the area.

Since the initiation of the research program, the Soil Conservation Service, in response to a request from this Department, has outlined a complete and systematic study of land and water and related resource problems of Humboldt River on a basinwide and a watershed basis. This study, which will be made in cooperation with this Department under authority of section 6 of Public Law 566, will furnish the overall background setting for the preparation of programs and the development of projects in the basin. Essential information and data from the research project will be utilized in this study. The study, in turn, will provide the vital connection between the research project and subsequent operations programs.

For the fiscal year 1960 program, the State appropriated $35,000. The U.S. Department of Agriculture's budget contains an appropriation of

$10,000 earmarked for the Agricultural Research Service's participation in this program.

Basic data inventory

The Department of Conservation and Natural Resources has initiated a program for the inventorying of basic data that is related to the State's water and land resources. A great deal of such data exists but is scattered around in various agencies and reports are not readily available.

A partial listing of the basic data to be inventoried is as follows:

Stream gaging records
Hydroclimatic records
Snow survey
Ground-water studies
Quality of water records
Topographic mapping coverage
Aerial picture coverage
Geological mapping coverage
Bureau of Mines reports
Soil studies coverage
Observation well coverage

This program is undertaken with the realization that to be effective it must be kept current.

Aerial mosaic program

It is proposed that this department enter into a cooperative program with the Soil Conservation Service in the preparation of mosaics that would cover the important valleys throughout the State. Such a program could be carried in a modest manner and be a long continuing one. A State appropriation of $1,500 for the fiscal year 1961 would be sufficient.

Topographic mapping program

This program has been underway for several years with excellent results. The work is carried on by the Governor's topographic mapping committee consisting of Vernon E. Scheid, director, Nevada Bureau of Mines; Frank W. Groves, director, Nevada Fish and Game Commission; Edward L. Pine, State highway engineer; Edmund A. Muth, State engineer; and Hugh A. Shamberger, director, department of conservation and natural resources, who serves as chairman.

This committee meets yearly with personnel of the U.S. Geological Survey, Topographic Division, and decides on the mapping program. The quadrangles are listed by priorities and the suggested program is submitted to the Washington, D.C., office. Since the inception of this program, the topographic mapping program has been greatly speeded up.

Nevada water conference

For a number of years a Nevada water conference has been held in Carson City. At this conference each State and Federal agency concerned with land, water, and related matters give brief reports on their activities in the State during the past year and plans for the coming year. In addition, several papers of interest to the conference have been presented by experts in the particular field. This program has resulted in a great deal of coordination between all the agencies involved. The reports are printed and made available to the public.

On October 1, 1959, the 13th such conference will be held at Carson City under the sponsorship of the department of conservation and natural resources and the Nevada State Reclamation Association.

Natural resources coordination committee

To better coordinate activities between the various agencies, Federal and State, on programs pertaining to the development, conservation, and uses, a natural resources coordinating committee has been recently appointed by Gov. Grant Sawyer. In addition to the State agencies, the Governor has asked the Bureau of Land Management, Forest Service, Soil Conservation Service, and Indian Service to participate.

One of the responsibilities of this committee will be the orderly planning of long-range programs in the field of natural resources.

Additional suggested programs

Weather modification.—Research on this program should be carried on as rapidly as possible. The problem in Nevada would be to increase the snowfall on the high watersheds so that spring and summer runoff would be increased.

Recently, in a discussion with Dr. Vincent J. Schaefer, director of research, Munitalp Foundation, Inc., Schenectady, N.Y., he told me that the area easterly of the Sierra Nevada Range would be an ideal location for research studies. It was Dr. Schaefer who, in 1946 with his co-workers at the General Electric Co., clearly demonstrated that supercooled clouds in a laboratory cold box and in the atmosphere could be modified by artificial means so that precipitation would take place.

Therefore, it is suggested that research studies on weather modification be carried on in northern Nevada.

Evaporation reduction.—Some research work in the reduction of evaporation on small stock reservoirs and ponds should be carried on.

Desalinization.—The matter of demineralization of saline waters is not of major importance in Nevada at the present time. A study could well be made, however, of the magnitude of the problem.

NEW HAMPSHIRE

State of New Hampshire,
Water Resources Board,
Concord, October 26, 1959.

Hon. Robert S. Kerr,
Chairman, Senate Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

Dear Senator Kerr: Your letter to Governor Powell has been referred to this department for an answer.

Water and water planning is important and you are to be congratulated for undertaking a comprehensive survey at this time. New Hampshire has been mindful of the problems involved and always willing to assist in work of this nature. We were associated with the New England-New York Inter-Agency Committee study of water and related land resources for New England and New York and have since worked for a Federal-State compact to implement the report. New Hampshire along with Massachusetts, Rhode Island and Connecticut have this year enacted the compact into law (see copy in appendix) and will shortly be asking Congress to pass the necessary legislation making the Federal Government a party.

It is earnestly requested that your committee give favorable consideration to what we are trying to do here in New England as manifested by the Northeastern Resources Committee. Since your staff will examine the New England-New York Inter-Agency Committee report, it is not necessary to be repetitious by covering this material in detail. There are, however, a few salient facts that should be underlined by restatement.

It is believed important and we recommend that your committee give particular consideration to the following:

1. Some form of flood plain zoning should be adopted. Since Federal funds are used almost exclusively for flood control projects, maybe they should be appropriated only on the condition that the State or communities, or both, shall adopt adequate zoning ordinances.
2. We need to know more about our ground-water supplies. A more extensive ground-water program to the point of quantitative and qualitative determination would be desirable.
3. Conservation storage for stream regulation for general public benefits during the low-flow months are needed. Maybe this should be a joint State- and Federal-sponsored venture.
4. There should be given greater consideration for provisions for recreation and fish and wildlife for all water projects such as those under Public Law 566, flood control by Army Engineers, etc., whether or not the project is located in or out of the national forests. Earmarked funds for advanced planning of this feature in all water projects is necessary.
5. Weather modification knowledge will become more and more important in the next 20 years. Intensive research should be undertaken in the form of a joint venture between the States and the Federal Government.
6. More research is needed to develop basic data. To name one example: "Data on runoff as affected by land management."

In assembling this information for your committee, all the resources agencies in State government and some of the Federal agencies thought directly concerned were asked to furnish us with information. Their replies are appended hereto.

Very truly yours,

Walter G. White, *Chairman.*

State Department of Health,
Division of Sanitary Engineering,
Concord, N.H., July 31, 1959.

Mr. Walter White,
Chairman, Water Resources Board, Concord, N.H.

Dear Mr. White: This is in reference to your earlier inquiry concerning aspects of water-resource problems with which this office is concerned. Inasmuch as I serve in the dual capacity of director of sanitary engineering in the health department and technical secretary of the water pollution commission, I will attempt to cover the total picture with relation to public water supplies and pollution control in the one letter.

With reference to domestic water supplies, there are at present some 138 systems in the State ranging in size from those serving a very small population of about 50 people, to the Manchester waterworks, which is now providing water for about 88,000 people. It is estimated that the waterworks systems of the State serve approximately in excess of 80 percent of the population and the tendency is for this percentage to increase from year to year as population grows. Formerly many of these utilities owned privately but in more recent years public ownership has become the prevailing practice. As of the time of this report 106 systems are municipally owned and only 32 are privately controlled and for the most part these are the smaller systems, the major exception being the case of the Pennichuck waterworks serving the city of Nashua which is the second largest water supply in the State and serves about 38,000 people.

Of the total number of supplies, 83 are surface sources, either from lakes and ponds or streams. The number of ground-water systems amounts to 55 and in recent years it is apparent that the tendency, particularly for smaller communities is toward the development of ground-water sources rather than surface systems. There are two principal reasons for this trend, one of which is the fact that with the continued recreational development, it is increasingly difficult to find lakes or ponds which can be utilized with simple treatment alone, such as chlorination.

Secondly, ground water (with some notable exceptions) is apt to be more uniform in character throughout the year and oftentimes is more readily available close to the area where water service is required. Thus where limited quantities of water are needed, a ground-water development is usually selected for communities of nominal size. For larger cities or in the case of an area, surface sources are more apt to be chosen because of safe yield considerations. Obviously, however, in deciding as to whether auxiliary or new supplies shall be developed from ground-water reserves or from surface sources, in the final analysis, the question of economics is the determining factor.

In our judgment, there is no present problem of inadequate domestic water resources in the State. It is apparent from previous records and investigations that there are ample supplies to take care of the needs for many years in the future. This is not to say, however, that communities or groups of communities within the State are not confronted with water problems. The major difficulty to be resolved lies in the fact that in most instances the easily available, low-cost water-supply developments have taken place. Communities will now have to contemplate the additional higher costs occasioned by the investment needed to develop the more remote sources of water supply. This is particularly true of the seacoast area where surface sources are limited and ground-water reserves have been developed to a high degree.

With reference to the matter of water quality, New Hampshire is relatively fortunate as compared with other areas in the country. Our supplies, both ground and surface, tend to be relatively soft with an average hardness for ground supplies being in the range of 30 to 50 parts per million. Surface supplies will generally range in hardness between 10 and 25 parts per million. Exceptions to these averages would be found in the seacoast area and along the Connecticut River, where the ground supplies tend to be somewhat harder. Even under these circumstances, however, it is unusual for the natural hardness to exceed 100 parts per million.

In ground supplies, iron may be a natural constituent and, if present in sufficient amount, removal facilities are necessary. Frequently for public systems a lengthy test period is conducted so as to evaluate any potential iron problem. In order to avoid the necessity for removal equipment, the test procedures are often extended over wide areas so as to locate sources where iron is entirely absent or present only to a minor degree.

Manganese has been a problem occasionally but this is comparatively rare and hence is not regarded as a serious threat to water quality.

It perhaps should be mentioned that experience has demonstrated that excessive pumping of individual ground sources or excessive development of one watershed by installing a number of wells therein may induce an iron problem. The exact reasons for increased iron content under conditions of increased pumpage are not known but the results have been observed.

As concerns surface waters, by and large those which are utilized for domestic water supply purposes are relatively free of natural color, low in organic matter, and require a minimum of treatment in order to insure potability. This observation as to treatment is made, of course, with the understanding that restrictions are placed upon nonconforming uses of the particular waters involved.

Finally, with reference to quality considerations, New Hampshire waters are acid as well as being soft, the combination of which tends to produce an aggressive, corrosive supply. Some communities in the State are employing corrosion-control treatment in the interest of protecting the distribution systems and also to reduce corrosive attack on the plumbing systems serving individual properties connected to the public system. Efforts are being made by the department periodically, in our contacts with water-supply management, to encourage the adoption of corrosion-control practices.

With reference to water use, our records indicate that about 500,000 people in the State are currently being served by public systems and that the average consumption per capita is 100 gallons daily. These are exceptions to the average, as for example in Manchester where the per capita consumption is 150 gallons per day. Overall it is expected that by 1980 the average consumption will increase to 150 gallons per day, and that by the year 2,000 the consumption rate will reach 200 or more gallons per person per day.

Conventional treatment methods are being improved by the use of new coagulants and changes in filter design and filtration techniques. Rapid sand filtration rates, for example, have been increased to 4 to 5 gallons per minute per square foot of surface area. Quality control through the use of breakpoint chlorination is now well established. We are looking forward with interest to developments in the desalinization of salt water. This treatment, when costs are reduced to a more economical level, would be of special benefit to our seacoast communities. We are also aware of work being done especially in the west-coast area in the recharging of ground waters with treated waste water. The necessity for this method of water conservation has not been demonstrated as yet in New Hampshire.

So far as water use for pollution abatement is concerned, it is assumed that reference is made to the diversion of water from one basin to another for direct dilution purposes. Also reference could be had to multiple-use dams which are designed to maintain minimum flows higher than normal. At this time we are not familiar with any necessity for diversion from one watershed to another, however, any multiple-use storage, such as for flood control, power, recreation, or for other reasons, would certainly tend to assist any downstream pollution problems if provision could be made for release of stored waters during critical periods of the season when runoff is low and temperatures are high.

Under the present contruction-grant system available under Public Law 660, 84th Congress, storage projects for reasons of pollution control alone are not eligible for assistance, hence it is unlikely that projects of this type would be considered in New Hampshire.

Finally, with reference to pollution control, it is apparent that the construction of pollution-control projects, either of a primary treatment nature or complete, will tend to encourage and enhance present and potential downstream uses. As such, the program has the distinct aspect of promoting reuse and conservation of our surface waters.

Very truly yours,

WILLIAM A. HEALY, *Director.*

STATE OF NEW HAMPSHIRE INTERDEPARTMENT COMMUNICATION

AUGUST 18, 1959.

From: Russell B. Tobey, director of recreation.
To: Walter G. White, chairman, New Hampshire Water Resources Board.
Subject: Information for Committee on National Water Resources.

Thank you for the opportunity to contribute information for a State park point of view to Senator Kerr's special committee. I trust that the following will be of interest and be helpful in studies to resolve the competition for the uses of water. In our State it will be important to provide access for recreational uses in the future as well as for other purposes.

It would seem to be very desirable to have the council on resources and development review the material you are assembling from various sources for the Senate committee.

Going over the outline of information desired, it appears that our comments would be confined to Roman numeral II–H to which I respond as follows:

Attendance at State parks where beaches provide the principal appeal have been rapidly increasing with the years. This is shown by the following attendance figures at parks in this category. These figures are quite accurate as at each of these parks we have a per capita service charge. These figures are for calendar 1952–57 unless otherwise noted.

Echo Lake State Park	9, 321	26, 833	Wadleigh State Park	6, 802	24, 545
Forest Lake State Park	6, 386	21, 302	Wellington State Park	41, 264	43, 920
Kingston State Park	72, 526	99, 982	Wentworth State Park	11, 762	20, 276
Silver Lake State Park (1955)	57, 872	77, 162			

Under the circumstances resulting from this growth we are experiencing serious overcrowding of facilities and are now setting limits to our capacity at several parks. This results in turning away large numbers of people during periods of prolonged peak use.

State purchases for the development of public State park beaches has, over the years, shown a rapid increase in the cost of this property.

White Lake State Park, 1950, 7,233 frontage-feet, $30,000.
Kona Farm property, 1956, 3,000 frontage-feet, $100,000.
Ellacoya State Park, 1957, 600 frontage-feet, $75,000.

Legislation in recent years has established special commissions to investigate the purchase of property for parks with beaches. In the current session of the general court, legislation is being considered to authorize this State department to investigate two potential park sites with water uses as their major purpose. There is even some expression of an unofficial policy that public water sites should be acquired on all of our major water bodies as well as on our seacoast. Suitable sites are becoming more scrace—more expensive—and are often involved with private developments which are presently contributing to local taxes.

Because of scarcity, prices, and disruption to private developments, it is possible that artificial impoundments or the creation of artificial beaches may be feasible in the near future. To justify the cost of impoundments, it may be necessary to explore the worth of a water body to the local community, to the State, to the fisherman, for boating, for water conservation, for any flood-control aspects as well as for State park purposes. Such an economic study would be worthy of the committee's attention.

Sincerely,

RUSSELL B. TOBEY,
Director of Recreation.

State of New Hampshire Interdepartment Communication

From: State planning and development commission.
From: Winfred L. Foss, industrial director.
To: Mr. Walter G. White, chairman, New Hampshire Water Resources Board, Concord, N.H.
Subject: Your memorandum of July 6 re information for use of Senator Robert S. Kerr's Senate Select Committee on National Water Resources.

Items A, C, and D, section II, of your "General Outline of Proposed Procedures" are the only ones which seem to come within the experience of this commission. These are: A. Population projections, C. Agricultural use of water, and D. Water needs of industries (including atomic).

Attached is our population projection for the period 1960–80.

In the matter of agricultural use of water, we do not have at hand any supportable estimates on the amount currently used. The only observation that we can make on this subject is that it would be our impression that agricultural activities in the State of New Hampshire can be expected to diminish, rather than increase, in the period between 1960 and 1980.

We find ourselves in the same position in respect to an estimate of the water needs of industries (including atomic). Our understanding is that for the immediate future there are no plans to locate atomic power operations in the State of New Hampshire, and there does not seem to be demonstrated any immediate economic advantage from the standpoint of power costs to do so.

Our daily contact with out-of-State industry indicating interest in New Hampshire as a location for their operations would seem to indicate that the large portion of those companies receptive to such moves have manufacturing processes which do not require large quantities of water. In most cases where water is an important consideration, it is important from the standpoint of being a coolant and, as such, is returned to its source unpolluted.

Statement on Population Projection, State of New Hampshire, 1960–1980

The resident population of New Hampshire on July 1, 1958, was estimated to be 583,000. U.S. Census estimate for July 1, 1959, is not yet available.

It is felt that New Hampshire's resident population will show definite increase in the next two decades and that the State's total population may range in the following envelope:

1960	590, 000–610, 000
1965	620, 000–640, 000
1970	640, 000–675, 000
1975	660, 000–710, 000
1980	675, 000–740, 000

State population studies indicate a decline in permanent population in most of the townships in the northern portion of the State, with the exception of a few industrial communities. However, seasonal occupancy of dwellings will likely increase substantially both in the northern part of the State and elsewhere. Sizable population growth is expected to occur along the Massachusetts border, particularly in southeastern New Hampshire, and along the Connecticut River Valley, the Merrimack River Valley and the seacoast-Great Bay area of the State in the period 1960–80.

State of New Hampshire,
Forestry and Recreation Commission,
Concord, August 7, 1959.

Mr. Walter G. White,
Chairman, New Hampshire Water Resources Board, State House Annex,
Concord, N.H.

Dear Walter: Reference is made to your letter requesting our thoughts that might be helpful to the Senate Select Committee on National Water Resources.

I believe we all recognize that to derive the maximum benefits from our watersheds with the end result that more and better water is available for domestic and industrial uses, a coordinated team or group effort will be necessary. Inasmuch as New Hampshire is 86-percent wooded, we can assume for the most part our watersheds are forested in one form or another. We also should recognize that a very large percentage of the land making up said watersheds are in private ownership.

With the aforementioned hypothesis in mind, I would like to recommend the following points for consideration:

1. I believe our first step would be to accurately map our more important watersheds in the State needing attention which would show the land involved and give us the basis for analyzing our problem.
2. I would also suggest that after completion of (1), above, that the Soil Conservation Service be given the responsibility of categorizing the land in each watershed by soil classification.

With this information at hand, the State and Federal forestry agencies would then be in a position to work with the individual small woodlot owners whose land make up these watersheds and guide management practices on such areas toward maximum watershed benefit. For instance, we will know from the soil whether or not we should be managing a given area for hardwood or softwood production. This fact will enable the woodlot owner to produce quantity and quality timber that is best suited for his particular holding. By the same token, we know that there is considerable difference in transpiration rate, in soil compaction and absorption between hardwood and softwood stands of timber. We know at the present time that hardwood is growing on typical softwood sites and that woodlot owners at considerable expense are attempting to grow high-quality pine on hardwood sites. In short, if point (1) and (2) above were carried out, it would be beneficial to everyone. It would be beneficial to the landowner since he would have a knowledge of what type of timber he should grow on his land. It would be of value in watershed planning since an accurate determination could be made of the water potential in a normal year.

As far as forestry is concerned I believe considerable more research must be carried out to determine the influence of various types of forest management on runoff and ground water supplies. In recent years some work has been done along this line but many answers are yet to be found. I feel the responsibility of the forestry agencies is to manage and protect the forest cover in these watersheds so that the maximum water yield may be realized for downstream use. As to the other phases of the watershed management program such as impoundment, disposition, use, of the water in the final analysis is not our problem. We do, however, have a real responsibility to integrate woodlog management with the interests of watershed management and to protect such areas from fire and disease which would greatly influence water reserves availability and runoff.

Very sincerely yours,

WM. H. MESSECK, Jr., *State Forester.*

NEW HAMPSHIRE STATE PORT AUTHORITY,
COUNTY COURT HOUSE,
Portsmouth, N.H., August 7, 1959.

Mr. WALTER G. WHITE,
Chairman, State of New Hampshire Water Resources Board,
Concord, N.H.

DEAR WALTER: Please pardon my delay in replying to your letter of July 7. We are rebuilding one of our tugboats in Boothbay Harbor, Maine, and I have been spending most of my time there; so consequently, attending to my correspondence has been sadly neglected.

We have not had a meeting of the port authority since your letter was received, therefore, I am not in a position to comment on the general outline of proposed procedures. As far as I am concerned personally, there is one project locally that I am very much interested in and that is a study of the possibility of damming Great Bay which would accomplish many things.

I believe you are quite familiar with previous studies. I do feel, however, that they should be reviewed and possibly brought up to date, particularly with the end in view of making a huge reservoir of Great and Little Bay which would be retained by a dam and could be the future water supply of this whole area.

I would welcome an opportunity at some convenient time to discuss the many advantages that would accrue with a dam.

With kindest regards, I remain,

Very truly yours,

JOHN E. SEYBOLT, *Chairman.*

U.S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE,
WHITE MOUNTAIN NATIONAL FOREST,
Laconia, N.H., July 29, 1959.

Mr. WALTER G. WHITE,
Chairman, New Hampshire Water Resources Board,
Concord, N.H.

DEAR WALTER: Further reference is made to your letter of July 7.

As indicated in my letter of July 10, we have given your outline of proposed procedures to be used in assembling data for the Senate Select Committee on National Forest Water Resources, a rather thorough study. We find it most complete and yet concise. I have only a few comments to make, but they seem to be quite important from the viewpoint of a land manager.

Beginning on page 11 of the attached booklet is a rather condensed summary of the needs of all the national forests to provide for full watershed management objectives. In New Hampshire the studies in the Hubbard Brook Hydrological Laboratory on watershed uses and manipulation, in the light of quality and quantity production of water, should be stepped up to provide positive guidance at the earliest possible date. Elsewhere on the national forest we recognize the needs for fuller management and administration of our soil and water resources, and particularly the sizable job of rehabilitating slide areas and stabilizing logging roads and streams. We certainly need a more complete inventory of our water resources as well as better data on water yield.

Sometimes we overlook the fact that in New Hampshire somewhere around 85 percent of our annual precipitation falls on forest land and that management of these forested areas is reflected in the quality and quantity of water yield. This percentage may well be higher when we consider that the areas of the State receiving the heaviest rainfall are in the forested zones.

I was very happy to note that you are going to see that forestry as it relates to the entire field of our water resource is not overlooked. We are very interested in all phases of this study and particularly the following:

1. Relationship of forested watersheds to projects recommended.
2. Provision for recreation and fish and wildlife considerations when projects are located within national forest boundaries.
3. Need for data that the committee's studies develop concerning forest land management as related to water production and other benefits of the water resource.
4. Any projects recommended for the White Mountain National Forest.

I appreciate your giving us an opportunity to review your outline, and trust that you will keep us advised of developments.

With kindest regards,

G. S. WHEELER, *Forest Supervisor.*

STATE OF NEW HAMPSHIRE, INTERDEPARTMENT COMMUNICATION

OCTOBER 5, 1959.

From: Perley I. Fitts, commissioner, department of agriculture.
To: Mr. Walter G. White, chairman, New Hampshire Water Resources Board.

DEAR WALTER: Some time ago you wrote me regarding Senator Robert S. Kerr's Senate Select Committee on National Water Resources, and asked for certain information particularly in regards to agriculture. I am sure that you understand that we have no funds to carry on surveys such as would furnish information in this field.

I believe I did tell you, however, that at a meeting in Durham on August 10 entitled "Agricultural Adjustment Seminar," Dirk Van der Voet, of the Soil Conservation Service, presented figures in connection with an "Inventory of Soil and Water Conservation Needs in New Hampshire, Present to 1975." I made a few penciled notations at the time indicating the scope of his study. The subheadings being the amount of Federal land in 1957 and that expected in 1975, and the other six categories being: Urban use, water storage facilities, cropland, pastureland, forest cover, and miscellaneous. I understood at the time that these figures were to be released from his office shortly, but as I remember them, both cropland and pasture for agricultural purposes were expected to drop. Federal land, urban use, and forest land were all expected to increase between now and 1975. I would suggest that you contact Mr. Van der Voet if you would like the details of this study, as I feel they are the only ones that have the agricultural application that you are thinking about.

STATE OF NEW HAMPSHIRE, INTERDEPARTMENT COMMUNICATION

AUGUST 4, 1959.

From: Ralph G. Carpenter, 2d, director, fish and game department.
To: Walter G. White, chairman, New Hampshire Water Resources Board, State House Annex, Concord, N.H.

This is in reply to your memorandum of July 6 to which you had attached a general outline of the proposed procedures to be used by the Senate Select Committee on National Water Resources.

Our department has no specific proposals to make. However, since it is self-evident that the recreational use of water in the future will increase in relationship with the increase of population, leisure time and income, we would like to make the following general recommendations—

1. The legal status of streams and their use by the public should be clarified. We believe that all streams should be the property of the public.
2. Due to increased importance of water in recreation, we seriously urge that the present trend to abate the use of water for sewerage and waste disposal be continued and accelerated; and the long-range plans be to discontinue the use of all open waters for sewerage and waste disposal.
3. We urge extreme caution in any future plans to drain marshes and wet lowlands; since such practices not only have adverse effects on many forms of wildlife, but also on the subterranean water table.
4. Any future plans to make major alterations of our coastal estuaries should be done only after careful study of their effect on offshore marine life.

RALPH G. CARPENTER, 2d, *Director.*

NEW JERSEY

State of New Jersey,
Department of Conservation and Economic Development,
Trenton, N.J., October 1, 1959.

Hon. Robert S. Kerr,
Chairman, U.S. Senate Select Committee on National Water Resources,
Washington, D.C.

Dear Senator Kerr: I am transmitting a report on the water resources problems of the State of New Jersey for consideration by the Senate Select Committee on National Water Resources as requested by you in your letter of June 23, 1959. I sincerely hope this report will assist the committee in its task of assembling and analyzing information on the Nation's water resources problems.

Both water problems and policy matters are included in the body of this report. If the committee work staff desires further information, the State of New Jersey will be glad to assist in any way it can.

We in New Jersey thank you for the opportunity to participate in this worthwhile effort.

Sincerely yours,

Salvatore A. Bontempo, *Commissioner.*

The Water Problems of the State of New Jersey

A Report to the U.S. Senate Select Committee on National Water Resources prepared by the Division of Water Policy and Supply, Department of Conservation and Economic Development, State of New Jersey, October 1, 1959.

I

The State of New Jersey faces the uncomfortable fact that too much of its plentiful rainfall is allowed to run out to sea simply because adequate water storage facilities are not available to capture it. When water is needed, it is not available. No matter how plentiful New Jersey's rainfall may be, its water resources are limited by the amounts that can be captured and held for future use.

Water for north Jersey, particularly for the northeastern area, is one of the most pressing water problems facing the State today. This heavily populated, highly diversified, and highly developed industrial region requires more water now. The need for more adequate water storage facilities for supply to this region is particularly important for continued economic development of north Jersey where the major water resources are limited largely to surface water sources.

South Jersey faces equally important water resource problems. In this region, where nature has provided ample natural storage facilities in extensive sand formations to carry over surplus rainfall for use in less plentiful periods, the immediate problem is a lack of knowledge about the distribution and quality of ground waters available. Only through provision of reliable scientific data can these water resources, which are considered adequate for south Jersey's immediate and future needs, be properly protected and conserved.

The fact that these natural subsurface water resources are not visible to the naked eye can lead to the illusion that these supply sources are inexhaustible and are therefore available any time man wishes to tap them. Unless these water resources are properly protected, they are subject to destruction like any other natural resource. By proper balancing between withdrawal from and recharge of these natural reservoirs and properly protecting them against external pollution, much will have been done to assure that these resources are available as higher demands for water materialize.

Ground-water resources in south Jersey are vulnerable to damage. The ground-water aquifers in the highly important Coastal Plain region are surrounded on three sides by salt or brackish waters. The same geological conditions which enhance the natural development of ground-water resources in south Jersey also invite their destruction if man upsets the balance of nature. Heavy pumpage from aquifers along the New Jersey Atlantic coastline, Delaware Bay, and the brackish reaches of the Delaware River increase the danger of salt water intrusion as well as pollution from other sources. Long-range ground-water investigations are required for proper protection of these resources. The prime objective is to keep their destruction from materializing.

Thus, the primary water resource problems which demand immediate attention are: (1) the need for more adequate surface water storage facilities in north Jersey to meet present and future water demands. Better pollution control and stream flow regulation will, of course, be possible with their development; (2) the proper protection of New Jersey's ground-water resources. Extensive long-range ground-water investigations are required to properly meet the problem.

It can be said at the outset of this report that New Jersey, unlike some of its neighboring States, can meet its water requirements in the immediate future by the development of its intrastate water resources without interstate agreements and without the necessity of seeking approval from the Supreme Court of the United States. This rests, however, on the ability of this State to provide the required water storage facilities in the Raritan Valley which provides a potential of 300 million gallons daily of new waters, and to properly protect and develop its ground-water resources.

Long-range considerations indicate that New Jersey will have to begin development of its Delaware River water resources around the year 1980. Engineering studies indicate that New Jersey can meet its water requirements to the year 2000.

This State believes it has developed a sound approach to these problems. A sound approach does not mean the exclusion of socio-political factors and a preference for scientific determinations. It means an approach which takes into consideration the desires of the people as well as the scientific and technological requirements for a soundly engineered program of water resources development. Many years of both good and bad experiences in water problems have led to the creation of basic policies which, it is believed, will serve as guideposts to future development.

Hence, it seems logical and desirable to offer the select committee a summary explanation of the principles and procedures that have been developed as a result of New Jersey's efforts to assure its citizens that their water resources are properly developed and conserved. The true significance of these basic guides cannot, however, be clearly understood without some knowledge of the historical background of their development.

For many years the responsibility and authority for initiating and developing the water resources of New Jersey for the multitude of uses that have developed over the years were almost exclusively functions of the local municipalities. The ventures of the more populous municipalities beyond their local governmental boundaries in search of new sources of water supply had led, by the turn of the present century, to conflicts over the questions of "areas of origin," diversion rights, pollution and sewerage control, streamflow regulation, and a multitude of other problems.

The first really significant step taken to secure some State supervision occurred in 1907 when the New Jersey State Legislature passed a law (Surface Water Diversion Act) which established a State water supply commission with authority to equitably allocate and control the diversion of surface waters for public potable water supplies. This legislation also established certain principles designed to prevent the creation of insanitary conditions below the points of diversion. Considering the social and political climate of the times, the law was a bold step. In 1910 State control was extended to diversions of subsurface waters for public potable purposes.

Over the years the principle of just and equitable allocation has come to mean just and equitable allocation among inhabitants—not allocation among agencies providing water supplies. This is a unique and significant development in New Jersey's experiences in water resource problems.

The basic water right law for private use of both surface and ground waters in New Jersey is the riparian doctrine of the common law. The doctrine does not apply to surface or ground-water uses for public potable supply where the water is offered for sale off the property or properties from which it is obtained. Under specific legislation, the State assumes general supervision over all sources of public potable water supply. Where specific rights have been granted, the principles of prior appropriation apply, but to escape granting to perpetuity to private users of ground water, these grants are limited to definite periods. Grants given for public potable supply likewise have similar limitations. In 1947, the New Jersey Legislature modified the riparian doctrine as it applies to the private uses of ground water. Permission is now required from the State for any new diversions of ground water for private, industrial, irrigation, or other uses in excess of 100,000 gallons per day in delineated areas. No State control exists over the private use of surface water for either consumptive or nonconsumptive purposes. Legislation for control of private use of surface waters, patterned on the principles and procedures set forth in New Jersey's private ground-water law, is now under study.

In 1916 the legislature authorized the creation of the north and south Jersey water supply districts in order to expedite the development of water supplies. Various county and local water authorities and commissions have also been authorized over the years—again, with the same thought in mind—to find a practical solution to developing water supply shortages. It is not necessary to go further in this direction in order to indicate that a variety of methods have been tried. Many of the approaches to the water supply problem have been frustrating and detrimental to the primary need for proper use and development of New Jersey's water resources. There are volumes of records of cases at law which indicate that confusion has abounded in the past. But these experiences, both the good and the bad, have been valuable. The State of New Jersey has cautiously moved in the direction of State water resources development, and, as will be seen later, in a singularly unique way.

The search for and development of new sources of water supply have again brought into the open in recent years many of the conflicts inherent in water problems when local municipalities go beyond their boundaries to seek more water. It certainly would be a mistake, however, to come to the conclusion that little has been accomplished over the years in the water resources field in New Jersey. The people of New Jersey have maintained a strong faith in the principle of home rule in spite of a general trend in this Nation toward State and Federal control of functions normally thought to be local. There is a growing body of evidence which indicates that many State and Federal administrators are recasting their thinking about the relationships between Federal, State, and local governments. It is becoming more evident that high level administration of local functions does not always produce the best results. Perhaps the greatest single problem in New Jersey over the years has been that of finding a way to accommodate the principle of home rule with recognized values to be found in State control of certain aspects of water resources development. There is strong evidence to support the belief that a proper balance between local and State interests in water resources development has been struck in New Jersey. If this proves to be true, then much has been accomplished. It is certainly misleading to assume that policies guiding water resources development are correct simply because the countryside is dotted with glistening new water resource project installations. Progress cannot always be measured in terms of physical assets.

Take the problem of flood control—a subject in which the committee expresses an interest. This is a case in point. Billions of Federal dollars have been spent for the erection of flood protection installations throughout the Nation. Still the annual flood damage bill increases. Perhaps the primary reliance upon flood control works is an unsound approach to the problem. Perhaps the erection of flood control installations should be joined by programs for flood plain zining, for example. We need to recognize the indisputable fact that a flood plain is a natural stream's means for carrying excess waters during periods of flood conditions. This subject, of direct interest to New Jersey, will be discussed more fully later. It cannot be overly emphasized that sound policy in water resources development is critically needed; water is one of the prime factors which will determine this Nation's rate of future economic growth.

The State of New Jersey does not intend to enter into competition with municipal water authorities, local or county commissions, regional water districts, or public utilities in order to solve the State's most pressing water resources problem—adequate storage facilities to meet growing water shortages. What New Jersey does intend to do is to capture surplus waters, which would otherwise be lost, by the development of water storage facilities, and to augment the natural flows of its streams in order that all consumers may have the satisfaction of knowing that water is available when needed throughout the year. The point will be restated: New Jersey intends to augment its natural supplies of water for all consumers—nothing else is contemplated. This is the cornerstone of New Jersey's water supply law of 1958—a law which sets the basic policy for guiding both the State's immediate and future developments in water resources.

The last significant water-storage projects completed in this State were the Wanaque Reservoir, begun in 1930, and the Ramapo Reservoir, completed in 1953, to utilize the surplus storage capacity of the former. The State was not involved in either project. The State entered directly into the development of a water-supply project in 1944 when the legislature decided to rehabilitate the old Delaware and Raritan navigation canal to make available a new source of water for industrial and later for public use.

In 1954 the State extended its interest in water conservation by purchasing the Wharton tract in south Jersey to provide a ground-water preserve. In 1955 appropriations were approved for a long-range statewide ground-water research and investigation program. In 1956 and in 1958 similar measures were taken to protect potential sources of surface-water supply when the legislature authorized the acquisition of the Round Valley and Spruce Run Reservoir sites. Both sites are in the Raritan Valley which has been selected as the most feasible locale in which to begin immediate project developments.

The authorization to acquire these sites indicates a growing interest in a problem which promises to become more severe as time goes by. New Jersey is a rapidly growing small, highly developed State in which all reservoir sites are already, or shortly will be, at a premium for other uses. There are no "metropolitan islands" surrounded by spacious rural areas in the highly developed regions of this State. The growing complexity of this problem becomes self-evident.

The water-supply law of 1958, referred to before is the result of many years of experience in trying to find workable solutions to its primary water-resources problems. It is worth emphasizing the fact that the law represents a slow evolution in thinking on these matters. Numerous channels have been explored and found wanting. The care and thought that have gone into the formulation of this legislation have been thorough; it is a measure which establishes a basis for New Jersey's participation in the development of the Delaware Basin.

The principles and procedures found in this legislation are, therefore, a reflection of New Jersey's past experience in this field. In brief, the law provides for a threefold State water program: (*a*) Long-range planning for insuring the availability of adequate future supplies of water in all parts of the State; (*b*) long-range intensive investigations to assure the protection and sound development of the State's ground-water resources; (*c*) provision of new water to meet future demands of all users by the design, construction, and operation of storage facilities to augment the State's natural water resources.

The details of the law will not be discussed here. A copy of that legislation is included with this report as a reference source of information for the select committee. With minor modifications, the features of the surface water program are applicable to the development of New Jersey's ground-water sources of supply.

By developing water-storage facilities with proper provisions for streamflow regulation and other concomitant benefits, the State of New Jersey assumes the responsibility for the conservation of its natural-water resources, which is in the public interest, and to increase through the orderly development of those resources the availability of water for all interests during periods of natural low flow. No competition is created thereby in the delivery and distribution of water to areas of demand. The State merely insures the availability of water at higher sustained rates of flow for delivery by others to areas of demand. The principles, in general, apply to the development of New Jersey's ground-water resources. The objective is the same: to augment these natural-water resources in the public interest. The State recognizes that certain functions in water-resources development are not proper areas for State control.

It was envisioned at the outset of this report that the primary interest of the select committee would be in the assembly and analysis of information from the States which would describe both the basic water resources problems and the basic policy developments now in force or under consideration by the States in water resources matters.

The thought has been that underlying experiences leading to these policy developments become apparent in the discussion of policy formation. This approach has necessarily precluded an exacting description of the past experiences New Jersey has encountered. But enough has been provided, it is thought, to enable the committee to understand the basis behind State policies in water resource matters. We have concentrated our attention on the two primary problems facing New Jersey today. There is no question but that their solutions will enable the State of New Jersey to cope more comprehensively with future anticipated problems in water resources development.

II

There are other water resource problems in New Jersey which command attention. Some are of less relative importance now when considered beside the primary problems previously discussed. Others, such as flood control in the Passaic Valley, merit immediate attention, but cannot be adequately considered today because the State's resources for these purposes are very limited.

The general outline for the staff work of the Senate Select Committee on National Water Resources includes several topics which are of interest to New Jersey. Several will be commented on. One topic, new techniques in multiple-purpose water resources management, will be separately considered because of New Jersey's vital concern for the proper development of the water resources of the Delaware River Basin.

Irrigation

The use of ground and surface waters in New Jersey for supplemental irrigation is steadily increasing in New Jersey. This State is by far the heaviest user of water for this purpose in the Delaware River Valley as well as in its water-dependent areas. A highly developed truck-farming industry in south Jersey plus the readily available supplies of ground waters at shallow depths in this region are the primary reasons for this concentrated usage in New Jersey.

The rising demand for irrigation waters in areas less plentifully supplied with ground waters, however, calls for increased attention to the irrigation problems. As indicated in part I of this report, the State has no control over the private usage of surface waters for consumptive or nonconsumptive purposes. Users of surface waters for irrigation purposes will expect equitable allocation and dependable sources of supply.

There is need for the development of storage facilities on small streams to augment natural low flows and for legislation to regulate private uses of surface waters. Legislation for regulation of private use of surface waters is now under study. An adequate supply of surface waters in New Jersey for irrigation purposes depends heavily on meeting these two requirements.

Stream pollution

With a rapidly expanding industrial complex and growing population in New Jersey, the need for careful enforcement of stream pollution legislation becomes more critical. Good quality water is essential for continued economic growth. Streamflow regulation is a means for reducing pollution concentrations. The construction of storage facilities to provide water for release in periods of low flow is an essential part of an adequate antipollution program in New Jersey. The beginning point, of course, in any sound antipollution program, is to control contamination at its source. This calls for adequate enforcement facilities to carry out the intent of antipollution legislation.

Sanitary trunk sewage

The discussion above is directly associated with the problem of sanitary trunk sewage. Keeping pollutants out of streams altogether by conveying them out to sea through trunk sewers is an appealing means for attacking the pollution problem. But there are limitations which must be considered. New Jersey's streams and rivers are relatively small. Their low yields are inadequate for sustained consumptive uses. Water diverted to sanitary trunk sewers is a consumptive use and, unless compensated for, accentuates the water shortage problem. New Jersey is beyond the point where it can divert its waters to single purpose uses; this is an ill-afforded luxury. It is illogical, for example, to divert 10 million gallons of water daily out to sea for trunk sewerage purposes and at the same time build storage facilities to augment natural low flows by 10 million gallons daily without proper compensation for trunk sewer losses. There are cases in New Jersey where sanitary trunk sewer installations are economically desirable if compensating measures are applied.

Salt water conversion

In part I it was stated that salt and brackish waters threaten certain areas in south Jersey. With effective measures, control is possible. These waters, particularly the brackish types, are, however, potential sources of supplemental supply to certain areas in south Jersey where groundwater aquifers provide a limited supply of fresh waters. There is need for an economical process whereby these salt and brackish waters may be converted to usable fresh water.

Flood plain zoning

There is a need for effective flood plain zoning in New Jersey because expanding industrial and residential developments are beginning to seriously encroach into flood hazard areas. This is a subject which demands careful attention by everyone concerned with flood control. The flood damage problem is fundamentally the result of improper attention to land usage. A flood plain is a stream's natural means for carrying excess waters during periods of flood conditions. Once there is a proper regard for this, more can be done to reduce our tremendous annual flood losses. Flood control installations do not guarantee protection; reliance upon this method of flood control is proving to be an unsound approach to the problem.

Uncontrolled development and random growth of our cities over the last half century are basically responsible for the unwise encroachments on flood plains. The small communities today are the buds of the sprawling urban and metropolitan areas of tomorrow. The metropolitan "bursting at the seams" phenomenon is resulting in an accelerated invasion of flood hazard areas in New Jersey. One of the alarming things about this invasion is that it is occurring in many areas where extensive flood protection facilities are technologically impracticable or cannot be economically justified. Most of New Jersey's streams are not suited to the construction of flood protection installations of the order required under Federal programs. Without proper recognition on the part of the Federal Government of the value of flood plain zoning and due regard for the inadequacies of reliance upon flood protection works, the national bill for flood damages promises to increase over the years.

Flood insurance

A sound flood insurance program is an essential part of a sound flood plain zoning program. It may both implement and supplement such a program. A good flood risk insurance program is also one means of reducing the cost of flood protection projects. There is no conceivable flood protection project which might offer complete security; the higher the aim toward that goal, the higher the cost becomes. A good flood insurance program should specifically require that rates should be established in accordance with the risk involved.

Congress could aid the States in a number of ways. It could direct Federal agencies to assist the States in any way practicable in the preparation of reports to citizens setting forth measures available for reducing flood losses. It could authorize Federal agencies to assist the States in preparing maps and evaluation reports which provide basic data on flood magnitude and frequency in flood risk areas. Congress could require that Federal funds for protective works yielding localized benefits should be contingent upon regulatory action by State and local governments to control further encroachment upon floodways. On first reflection, it may appear that this last suggestion would be a Federal application of the carrot and stick principle. It is, however, a means whereby the Federal Government can help State officials responsible for flood control to convince local municipalities of the importance of maintaining stream floodways in a condition which permits them to carry off flood waters without needless property destruction.

There are, it is admitted, conflicting attitudes on the efficacy of flood plain zoning and flood risk insurance programs. However, the fact remains that the regulation of flood plain areas in New Jersey, which is experiencing a tremendous residential and industrial expansion, should be an essential part of a comprehensive flood prevention program.

Passaic Valley flood problem

The Passaic River is the source of New Jersey's most important flood problem. This river's watershed is an oval-shaped area covering 935 square miles of which 84 percent is located in and adjacent to the metropolitan area of northeastern New Jersey and the remainder in southern New York State.

At least seven detailed engineering studies of the flood control problem in this basin have been made over the last half century. Yet there is still no basin flood control program under way. It is readily apparent that flooding in the upper valley and along the lower river is a single problem which can be solved only by a comprehensive plan for the entire basin.

The implications of the metropolitan "overflow" into the valley, which is steadily mounting, are self-evident. The longer the flood problem in the Passaic Basin remains unsolved, the more difficult it becomes to economically justify a program of flood control. In the past most plans have provided only for the protection of the older highly developed lower valley. But time has altered the nature of the problem. Today, large portions of the central basin flood plain must be provided with the same degree of protection as the lower valley. The old saying that "an ounce of prevention is worth a pound of cure" has special significance in the Passaic Basin. The longer a flood control program is delayed, the higher the cost, both social and economic, of protecting the citizens of the basin. There is a point beyond which remedy becomes impossible.

It is therefore imperative that the flood problem in the Passaic Valley receives the attention it demands. The metropolitan region of northeastern New Jersey and southern New York State is a giant in economic importance to the people of the Nation. The flood problem in the Passaic Valley demands national attention.

Small stream channel clearance

As noted earlier, New Jersey is predominantly covered by small surface streams. Their importance, however, far outweighs considerations of size.

The ability of small streams to carry both normal and flood waters is seriously impeded by the lack of proper stream maintenance. There is need for the development and implementation of adequate stream clearance programs to restore and maintain the natural channel capacity of small streams in New Jersey. It must be realized that, given proper attention, the restoration and maintenance of natural stream channel capacity can significantly reduce, and in many cases eliminate, the need for costly manmade channel improvements. The local municipalities of New Jersey which border on small streams can procure more benefits from municipal resources devoted to water problems by giving more attention to natural channel restoration needs.

Adequate small stream channel maintenance helps to fulfill a number of important needs. It reduces the risk of destructive flash flood conditions. It assists in the maintenance of tolerable pollution conditions on small streams. And it helps to protect small streams for fishing and recreational uses.

It is often forgotten that small streams can provide multiple-use services to the citizen. It must be realized that the development of the small stream water resources of the Nation is just as important in many ways as the more larger type of stream development programs. It is essential that they be maintained in a condition which permits their full development when the times require it.

Hydropower development

The thermal type electrical power generation facility in the Delaware Basin and its service areas will not be supplanted in the near or foreseeable future by other methods of power production. In studies conducted by the Federal Power Commission it is estimated that a ninefold increase in the power requirements for the Delaware Basin and its service areas will occur between the present and the year 2010. The requirements of New Jersey figure heavily in these estimations.

This increase in power requirements must, of course, be met by economically justifiable means. The development of hydropower for peaking power purposes is an essential requirement in any economically sound formula for meeting those power needs. The large multiple-purpose type reservoir projects now being planned for the Delaware Basin offer an opportunity to meet these supplemental power demands.

III

The State of New Jersey has a threefold interest in the comprehensive multiple purpose development of the water resources of the Delaware River

Basin: this State desires a viable governmental structure, a competently organized administrative structure, and a well-planned and coordinated program of physical structural developments for the realization of the multiple purpose use potentials of the basin's water resources. Conceptually speaking, New Jersey's interest are two-pronged: First, this State's economic and social development is closely allied to the rate of economic and social development of the region of which this State is a part. Second, the rate of development of the region's natural resources influences, both directly and indirectly, New Jersey's efforts to meet its own domestic resources requirements by intrastate development. Good quality water in sufficient amounts is one of the primary requirements. New Jersey's water requirements must be considered from two aspects—the immediate and long-range needs. The State is in a position to meet the immediate requirements by intrastate development. But it was pointed out in part I of this report that New Jersey's long-range requirements can be met if this State's Delaware River Basin water resources are available when required and in a proper state of development. Hence, New Jersey, like its sister basin States, earnestly hopes for the comprehensive development of the Delaware's water resources.

The Delaware River Basin is located in one of the most highly industrialized and populous regions of the United States. Although the Delaware River system, when compared with that of the Tennessee or Missouri, is very small, it is a giant in terms of services to the States of New Jersey, New York, Pennsylvania, and Delaware—four of the most highly industrialized States in the Union. The Delaware River Basin between Trenton, N.J. and Wilmington, Del. is the fastest growing industrial area in the United States. Approximately 22 million people inhabit the Delaware River Basin service area. The Delaware is truly a David among the river Goliaths of the United States.

It is fully recognized that the sound and orderly development of the water resources of the Delaware River Basin is a regional problem which invites full cooperative efforts by all four basin States in seeking its solution. The principle of regional cooperation for solving regional water resources problems is fully accepted by the people of the State of New Jersey. There are ample precedents for believing that the basin States can by interstate cooperation provide a comprehensive program for developing the water resources of the Delaware. New Jersey, New York, Pennsylvania, and Delaware were among the first States in the Union to create interstate cooperation commissions. There is, therefore, a base of practical experience on which the basin States can build a comprehensive development program.

New Jersey realizes that the traditional unilateral approach to solving water resources problems is not adequate for the achievement of a comprehensive multiple program for the Delaware Basin. This State therefore has a special interest in a broad governmental-administrative-physical development program for the Delaware. New Jersey is deeply interested in the comprehensive survey of the water resources of the Delaware River Basin now being conducted by the U.S. Army Corps of Engineers. And, likewise, this State is very much interested in the governmental-administrative proposals prepared for the Delaware River Basin Advisory Committee through the services of the Water Research Foundation.

New Jersey has been actively engaged in promoting an integrated program for protecting and conserving the water resources of the Delaware River Basin since 1936. In that year, newly formed committees on interstate cooperation in the four basin States organized the Interstate Commission on the Delaware River Basin (INCODEL). One of the first tasks undertaken by INCODEL was to attack the pollution problem of the Delaware. The Delaware is no longer the shamefully polluted river of a quarter century ago. The successful pollution abatement program for the Delaware is living proof that the basin States can cooperate through interstate action for water resources development.

Twice during this century respective rights to the use of the waters of the Delaware Basin have become the subject of legal controversy, and in both cases the Supreme Court of the United States was called upon to render judgment. The bitter legal controversy of 1929–31 was one of the primary factors which led to the creation of INCODEL. Although it is true that certain specific and urgent water resources problems did receive close attention following the 1931 legal dispute, little was accomplished in the way of comprehensive water resources development for the Delaware River Basin. By the time of the second Supreme Court case of 1954, the positions of the basin States in regard to respective rights to the Delaware's water resources were better understood. This enabled the parties in the 1954 case to reach informal agreement in that year the Court decreed that New York City would be permitted to withdraw up to 800 million gallons daily and New Jersey 100 million gallons daily from the Delaware River Basin. It can be said that the absence of an accepted comprehensive development plan for the Delaware was the underlying reason for the resort to the Supreme Court in 1954.

In 1953 a broad basin water resources development plan, the effort of INCODEL, was almost accepted. In 1955 the basin States again renewed their efforts when the Governors of New Jersey, New York, Pennsylvania, and Delaware established the Delaware River Basin Advisory Committee to review further the water resources problems of the Delaware River Basin. Shortly after the disastrous hurricane of 1955 Congress directed the Army Corps of Engineers to restudy the flood problem of the Delaware River Basin. Early in 1960 this study, one of the most thorough comprehensive surveys of the water resources of any river basin in the United States, will be completed.

Below are listed several of the more important reasons why the basin States are deeply interested in a comprehensive program for the development of the Delaware River Basin. First, the economic and strategic importance of the water resources of this river valley to the continued high rate of industrial development of the basin States demands a comprehensive program for protecting and conserving the water resources of the Delaware River Basin. Second, the present governmental-administrative framework for cooperative action, which all the basin States desire, is not adequate for the task of making the comprehensive development of the Delaware a reality. There are a multitude of government and private agencies directly concerned with the water resources of the Delaware. This condition has led to a splintered administrative structure which is inadequate for realizing full cooperation. Limited geographic jurisdiction by each of the basin States necessitates a new approach to cooperative action. Third, the proper planning and administration of the Delaware River Basin's water resources calls for something more adequate than reliance upon the Supreme Court—the Court is not a planning or administrative agency.

There are additional and very specific reasons why the State of New Jersey is deeply concerned about the proper protection and conservation of this valley's water resources: First, and very important to New Jersey, the Delaware River is New Jersey's one major source of surface water supply. Second, New Jersey's water resources within the basin are considered an integral part of New Jersey's present plans to meet its long-range water needs and are already slated for extensive development around the year 1980. Third, a large portion of New Jersey's geographic area is within the Delaware Basin. Approximately 25 percent of the total area of this small State (8,225 square miles) is within that basin. Fourth, the recharge area for a high proportion of New Jersey's precious ground-water resources is within the basin's watershed boundary.

Thus, it is easily understood that New Jersey has a primary interest in the multiple-purpose development of the water resources of the Delaware River Basin. New Jersey desires a reasonable guarantee that the water resources of the Delaware will be properly developed so that when it becomes necessary to turn to the Delaware to meet increasing water demands, good quality water in sufficient amounts will be available. The only way that desired guarantee can be underwritten is when the comprehensive development of the Delaware is not a prophecy but a reality.

New Jersey desires a comprehensively planned and well administered program for the Delaware. A good reporting and research program for the Delaware is a long standing need of all the basin States. There is need for better standards of design, construction, operation, and maintenance of physical installations needed for the conservation, protection, and development of the Delaware's water resources. Technical and financial assistance in water resources development has been a long standing need. There is a critical need for the promotion and coordination of activities of all water resources and other related natural resources agencies in the basin. All these requirements can be met through a comprehensive program of development.

Interstate cooperation appears to be the best means for realizing these objectives. New techniques and ideas in multiple-purpose water resources management for the Delaware River Basin are certainly required. Interstate action, from all points of perspective, appears to be the logical path to follow. The Federal Government has many direct and varied interests in the water resources of the Delaware Valley. It is earnestly hoped that the Federal Government will assist the basin States in their efforts to make the comprehensive development of the water resources in this great river valley a reality.

NEW MEXICO

State of New Mexico,
State Engineer Office,
Santa Fe, September 30, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

My Dear Senator Kerr: Herewith in response to the request of your letter of June 23, 1959, to Governor Burroughs is a statement concerning the water resources problems of the State of New Mexico.

The State of New Mexico is appreciative of this opportunity to present its views to the Senate Select Committee on National Water Resources.

Yours very truly,

S. E. Reynolds, *State Engineer.*

New Mexico Statement to the U.S. Senate Select Committee on National Water Resources

(Presented in response to Senator Robert S. Kerr's letter of June 23, 1959, to Gov. John Burroughs)

INTRODUCTION

New Mexico contains portions of headwaters of three principal river systems of the United States. Figure 1 attached hereto shows the Mississippi River and western Gulf of Mexico tributary areas in green, the Colorado River tributary areas in blue, and the Rio Grande tributary areas including the Pecos River drainage in red. Twelve areas from which surface water does not discharge to principal streams are colored orange. Arrows indicate the general direction of motion of ground water from those areas.

All New Mexico's significant surface streams are subject to interstate water compacts. In fact, one of them, La Plata River, tributary to the San Juan, is subject to three compacts—the Colorado River compact of 1922, the upper Colorado River compact, and the La Plata River compact. Figure 2 illustrates the relationships of the various compacts and drainage areas.

When New Mexico has fully developed her surface-water resources within the limits of the compacts, the deliveries into the State under the compacts (principally from Colorado in the Rio Grande and the San Juan River) will approximately equal the outflow.

Table 1 summarizes the surface-water supply and usage for each of the major drainage basins in the State.

Figure 3 shows the underground-water basins which have been declared by the State engineer in accordance with New Mexico statutes. The legislature has declared all of the ground waters of the State to be public waters, but the State engineer has assumed administrative control over ground waters only in the areas indicated. A State permit is not required for the drilling of wells or the appropriation of ground water in other areas of the State.

Table 2 provides a summary of ground-water usage and conditions in each of the areas of the State where substantial amounts of ground water are used.

Stated simply, New Mexico's water-resources problem is to achieve the fullest possible development, conservation, and control of the resources within the limits of the interstate agreements and within the limits of economic feasibility in order to meet the needs of an expanding economy and population.

The trends in the State's population and economy are illustrated by exhibit 1, "Tentative Projections of the Population of New Mexico Counties," Bureau of Business Research, University of New Mexico; and exhibit 2, excerpt from "Annual Summary of New Mexico Business in 1958," Bureau of Business Research, University of New Mexico. Table 3 provides an estimate of the distribution of the population by drainage basin based on the data of exhibit 1. Table 4 sets forth projections of the population and estimated municipal and industrial water requirements of the Albuquerque metropolitan area through the year 1980.

A key factor in New Mexico's water-resources problem is the fact that agricultural pursuits will provide relatively little opportunity for increased employment, and progressively larger amounts of the State's water supply must be put to municipal and industrial uses to meet the needs of the expanding population. This fact was clearly recognized as early as 1950 in a Department of the Interior report (1).

New Mexico is a semiarid State with a relative scarcity of water; nevertheless, substantial quantities of the resource are not as yet developed for beneficial use. Plans for further development have been formulated and must be carried out expeditiously if the needs of the expanding population and economy of the State are to be met.

SURFACE WATER

San Juan Basin

The average annual recorded outflow from the State in the San Juan River is about 2,200,000 acre-feet. Under the Colorado River compacts the State of New Mexico may deplete the flow of the upper Colorado River system by about 840,000 acre-feet per year. Present depletions of the San Juan in New Mexico amount to only about 92,000 acre-feet per annum. Additional uses now authorized will cause a further depletion amounting to about 183,000 acre-feet per year. Plans for the development of New Mexico's share of the waters of the San Juan River under the Colorado River Storage Project Act are well advanced. The first unit of construction, Navajo Dam and Reservoir, with a capacity of 1,700,000 acre-feet, is about 37 percent complete. This regulatory unit of the Colorado River storage project will store water for the proposed 110,000-acre Navajo Indian irrigation project and the 3,900-acre Hammond project as well as water for future municipal and industrial needs in the San Juan Basin. The unit will also provide excellent opportunity for recreation and fish and wildlife propagation as well as flood and sediment control. Units that will be constructed under the storage project and the depletions that will be made by those units are set forth in table 5.

The initial stage of the San Juan-Chama project (2), which would be limited to an average diversion of 110,000 acre-feet per year, would provide water for the following depletions: 29,900 acre-feet in exchange for Rio Grande system water used on rehabilitated irrigation units on tributaries of the Rio Grande in northern New Mexico; 22,600 acre-feet for supplemental irrigation supplies for the Middle Rio Grande Conservancy District; 57,500 acre-feet for the city of Albuquerque. Allocation of about 5,200 acre-feet per annum of the latter amount for the establishment and maintenance of a permanent pool for recreation and fish and wildlife propagation in the proposed Cochiti reservoir is being considered. The plans contemplate that the San Juan-Chama project would be constructed so that the works could be extended by the construction of subsequent stages to provide for total diversions from the San Juan Basin to the Rio Grande Basin averaging up to 235,000 acre-feet per year. It should be noted that if the average annual diversion by the San Juan-Chama project is thus increased there must be a reduction in the amount of water available from Navajo Dam for depletion by municipal and industrial uses. (Estimated 112,500 acre-feet per year. See table 5.)

It is noteworthy that while initial stages of the plan for development of the waters of the San Juan River provide large amounts of new water for agricultural purposes, including the 110,000-acre Navajo Indian irrigation project, large amounts are also allocated for future municipal and industrial uses. The depletion amounts available to these latter purposes are summarized:

	Acre-feet
1. Available from Navajo Dam for municipal-industrial use under contract with the Secretary of the Interior	112, 500
2. Available from the San Juan-Chama diversion project for municipal-industrial use in the Rio Grande Basin	52, 300
3. Available to the Utah Construction Co. under State permit for the operation of a 1-million-kilowatt powerplant on the Navajo Reservation	39, 000
Total	203, 800

The project plan contemplates that the city of Albuquerque will pump ground water for its increased needs using the imported water to offset the effects of the increased pumping on the flows of the Rio Grande. Channel and reservoir losses on the 52,300 acre-feet imported for the city will leave about 45,500 acre-feet for depletion at Albuquerque. Since return flows from the municipal system are about 50 percent of the diversions, the imported water will allow a gross depletion of riverflows by ground-water pumping amounting to 91,000 acre-feet per year. Reference to table 4 shows that a diversion of 91,000 acre-feet per year added to the 1956 pumpage of 53,000 acre-feet would meet the needs of metropolitan Albuquerque to about 1975. This computation assumes that the new well fields would be constructed in the valley where the effects of pumping would be quickly reflected in the riverflows. It is likely that much of the increased pumping will be from wells on the mesa several miles from the river. For many years most of the withdrawals from these wells would be reflected in reductions in ground-water storage rather than in reductions in streamflow which would need to be offset by imported water. Therefore, the allocation to the city from the initial stage of the project will very likely meet the needs of the metropolitan area well beyond 1980.

Also, as the municipality grows it can be expected to encroach on the approximately 13,000 acres of presently irrigated, non-Indian land in the Albuquerque Division of the Middle Rio Grande Conservancy District. Water rights appurtenant to these lands, transferred to municipal use, would permit additional diversion of up to 52,000 acre-feet per year for such use.

Other municipal and industrial requirements in the Rio Grande Basin, which may arise before or after 1980, can be met with extensions of the diversion project. Whether these future needs will be met by such extensions will depend upon the time at which future needs arise in the San Juan and Rio Grande Basins and the State's judgment as to what distribution of the water resources of the San Juan Basin will best serve the public interest.

Early development of the water resources of the San Juan River is essential if the growing water needs of the State are to be met. The coordinated report on the San Juan-Chama and Navajo projects was transmitted to the Bureau of the Budget in September 1957 but that Bureau has not yet transmitted its recommendations on these reports to the Congress. The U.S. Senate has approved S. 72, 86th Congress (Senators Anderson and Chavez), which would authorize the Navajo irrigation project and the initial stage of the San Juan-Chama project, but House hearings on this legislation have not been set.

Serious flood control problems, aggravated by very rapid municipal and industrial growth, exist in the San Juan Basin in New Mexico. The Corps of Engineers is conducting a study of flood problems on the Animas River. This study is being coordinated with the State and with other Federal agencies. The corps is also cooperating with the Bureau of Reclamation in a study of operating criteria for Navajo Dam to maximize flood control benefits of that unit of the Colorado River storage project.

Rio Grande Basin

The major problems in the Rio Grande Basin of New Mexico have been the need for flood and sediment control, drainage, and the salvage of water lost to nonbeneficial plants (3). These problems were brought on by aggradation of the channel in the Middle Valley of the Rio Grande in New Mexico. The waters of the Rio Grande in New Mexico are fully appropriated and the problems affect not only the water supply of users in the Middle Valley but also the State's ability to meet the water delivery requirements of the Rio Grande compact. An attack on these problems was launched with the authorization of the Middle Rio Grande project in the Flood Control Act of 1948. Under this authorization 27 miles of levees have been completed in the Albuquerque reach of the river; Jemez Dam and Reservoir near the mouth of Jemez River are completed; Abiquiu Dam is under construction on the Chama River, a tributary to the Rio Grande; 87 miles of river channelization and rectification have been completed; rehabilitation of the drainage works of the Middle Rio Grande Conservancy District is almost complete, and about 53,200 acres of nonbeneficial water-consuming vegetation have been sprayed or cleared.

The Albuquerque District of the Corps of Engineers has recently completed a report on the proposed Cochiti and Galisteo Dams and Reservoirs. Cochiti Dam would be built on the main stem above Albuquerque, and Galisteo Dam would be built on Galisteo Creek, a major tributary (4). The States of New Mexico, Texas, and Colorado have reached agreement on operating procedures for these reservoirs. The reservoirs are immediately required for flood protection and sediment control in the Middle Valley and should be authorized and constructed at the earliest possible date.

The State has cooperated with the Bureau of Reclamation and the Middle Rio Grande Conservancy District in drainage and water-salvage works to supplement the work authorized under the Middle Rio Grande project. State expenditures from Ferguson Act funds from 1952 through June 30, 1960, will total $660,000. An additional $115,000 of these funds will have been spent for water-salvage work in the Caballo Reservoir area below Elephant Butte Dam.

It is estimated that work under the Middle Rio Grande project and the supplemental cooperative work will salvage from 150,000 to 200,000 acre-feet of the average annual nonbeneficial use of 570,000 acre-feet of the water shown in table 1. However, large amounts will still be lost to evaporation and transpiration from the Rio Grande in New Mexico and further studies of potential water salvage measures should be made. The Bureau of Reclamation is planning such studies (5), and it is contemplated that the State will be able to cooperate in the studies using Ferguson Act funds.

Pecos River Basin

The surface waters of the Pecos River drainage basin in New Mexico are fully appropriated. The waters are apportioned between the States of Texas and New Mexico by the Pecos River Compact which was approved by the Congress of the United States in 1949. The principal problems of the Pecos River are siltation of existing reservoir capacity and the river channel, salinity, flood control, and nonbeneficial consumptive use of water by evaporation and transpiration. These problems are presently acute and conditions will worsen unless corrective action is taken.

The Federal agencies, the Pecos River Compact Commission, the States of New Mexico and Texas, and local interests are cooperating to develop solutions to the problems of the Pecos River. Los Esteros Dam is proposed by the Corps of Engineers (6), for construction on the river at a point about 7 miles above the town of Santa Rosa. These works would provide flood protection and conservation storage to replace conservation capacity in Alamogordo Reservoir. It is estimated that, under present conditions, siltation will make this latter reservoir ineffective as upstream storage for the Carlsbad Irrigation District within about 40 years. Los Esteros Dam was authorized by Public Law 780, 83d Congress, but construction cannot be undertaken until the Carlsbad Irrigation District agrees to transfer a part of its conservation storage from Alamogordo Reservoir to the proposed Los Esteros Reservoir to provide flood-control capacity in the former. The district's consideration of that transfer is awaiting the formulation of principles for the operation of Los Esteros Reservoir by the Pecos River Compact Commission.

Public Law 85-333 authorized the McMillan Delta water salvage project and the Malaga Bend salinity alleviation project (7). The water salvage project contemplates the construction of a low-flow conveyance channel and a cleared floodway through the delta of McMillan Reservoir, the terminal storage of the Carlsbad Irrigation District. It is estimated that these works would salvage approximately 21,000 acre-feet of water per year that is presently nonbeneficially used. The legislation provides that the floodway shall not be cleared until provision is made to replace McMillan Reservoir storage capacity that would be lost by accelerated siltation resulting from the floodway clearance. The Carlsbad Irrigation District has accomplished some channel improvement and drainage work in the delta. The Bureau of Reclamation is currently studying the feasibility of constructing a low-flow conveyance channel without a cleared floodway and the practicability of utilizing as a part of the low-flow channel the work already constructed by the district.

There are about 420 tons per day of dissolved solids (mostly sodium chloride) discharging into the Pecos River at Malaga Bend. The authorized salinity alleviation project is designed to cut off this accretion by pumping the brine aquifer and disposing of the pumped brine by evaporation from a surface reservoir. Benefits of the salinity alleviation would accrue almost exclusively to the Red Bluff Waterpower Control District in Texas.

A recent report by the Bureau of Reclamation (8) which is currently under informal review by affected interests describes a plan of development for water salvage, flood control, and replacement of conservation storage on the Pecos River. This plan includes construction of the authorized Los Esteros Dam and Reservoir and the construction of Brantley Dam and Reservoir to a capacity of 297,000 acre-feet at a site about 4 miles downstream from the existing McMillan Dam. Brantley Dam and Reservoir would provide sediment control, flood protection, and conservation storage for the Carlsbad Irrigation District, to replace that function of McMillan Reservoir, as well as permament pool for recreation and fish and wildlife propagation. Some storage capacity in McMillan Reservoir would be retained for fish and wildlife propagation.

The Bureau report describes a comprehensive plan for water salvage in the reach of the river from Alamogordo Reservoir to Carlsbad. The data in the report suggest that the amount salvageable under present conditions is approximately 75,000 acre-feet per annum. The report emphasizes that unless corrective action is taken nonbeneficial consumptive use may be expected to increase markedly in the next 50 years, ultimately depleting the water supply by almost 340,000 acre-feet annually.

The Bureau of Reclamation report also describes studies of the feasibility of rehabilitating small community ditch projects totaling 15,160 acres in the upper basin of the Pecos River. Economic distress of the water users in this area is serious with a large percentage of the people requiring public assistance. The numerous diversion works are temporary or semipermanent in nature, requiring increasing costs and efforts to maintain. The distribution works are generally badly deteriorated. The 1959 session of the State legislature appropriated $100,000 to provide assistance in meeting the most urgently required rehabilitation work. This expenditure will make only a minor contribution to the solution of the problem because high operation and maintenance costs and water shortages will still be encountered without complete rehabilitation of the diversion and distribution works. The financing of such rehabilitation is beyond the ability of the State and local interests. The problem is a difficult one because the arable lands are widely scattered along the river and its tributaries, and because ownership is in very small tracts.

According to the Bureau of Reclamation report it is feasible to combine and rehabilitate only two of these community ditch units, combining them in a project totaling about 1,800 acres; however, even in this instance the repayment ability of the water users is questionable.

Further study should be given the economic feasibility of rehabilitating the other units. These further studies should give careful attention to possibilities for encouraging consolidation of ownership and the economic effects of such consolidation. It is believed that the Bureau of Reclamation techniques for analysis of irrigation projects do not fully reflect the benefits to be realized from the rehabilitation of projects in areas of substandard living conditions and economic decline, particularly where the ownership is in small tracts. For example, the analyses do not evaluate social benefits. Also, the economic analyses of the small units on the Pecos River do not reflect that the presently irrigated acreage will decline if rehabilitation is not accomplished. If this decline, which appears certain, were taken into account project benefit-cost ratios showing that rehabilitation of the units is justified might result. In this connection it is important to recognize that the crop pattern will change to include crops of higher value, as food and fiber shortages develop prior to 1980, rather than remain static as assumed for the analyses thus far made.

The Bureau report also discusses the power potentialities in the Pecos Gorge near the mouth of the river, concluding that the power project is not presently economically justified. Continuing attention should be given this potential power project and it should be developed at the earliest possible time in order that a basin account can be established to provide financial assistance in meeting the problems of the Pecos River. The basin power account could be used to repay to the Federal Government construction and rehabilitation costs beyond the ability of the water users to pay.

Gila Basin

New Mexico, in her role as a lower basin State under the Colorado River Compact, is a party in Supreme Court litigation (*Arizona* v. *California*) over the waters of the Lower Colorado River system. In this litigation New Mexico has asked for an equitable apportionment which would permit substantial new uses from Lower Colorado River tributaries in New Mexico. Present and proposed new uses from these tributaries in New Mexico are set forth in table 6. The contemplated ultimate total depletion at sites of use amounts to 111,700 acre-feet, or approximately 56,700 acre-feet more than the present depletions.

Planning for further development of the Gila River and its tributaries in New Mexico has been conducted by the State, the Bureau of Reclamation, and the Corps of Engineers. Further consideration of these plans awaits a decree in the current litigation. It is contemplated that the State will require the assistance of the Bureau, the corps, and other Federal agencies in developing and carrying out these plans.

Canadian River

The Canadian River Compact provides that New Mexico shall have free and unrestricted use of all waters originating in the drainage basin of the Canadian River in New Mexico below Conchas Dam, provided that the amount of conservation storage in New Mexico available for impounding these waters shall be limited to an aggregate of 200,000 acre-feet.

An act of the 1959 State legislature authorized the New Mexico Interstate Stream Commission to issue bonds guaranteed by $5 million of severance tax revenues to finance the construction of dams on the Canadian River or its tributaries between Conchas Dam and the Texas border. The act also provides that the severance tax funds used to pay the interest and principal of the bonds shall be repaid from water revenues as they become available.

Preliminary studies indicate that the initial stage of a dam and reservoir having an ultimate capacity of about 365,000 acre-feet can be constructed for about $5 million. The dam would be constructed on Canadian River just below the confluence with Ute Creek. The initial stage, having a total capacity of about 170,000 acre-feet, would yield about 40,000 acre-feet of water per year. This water would be used for agricultural and municipal and industrial purposes. Flood and sediment control, recreation, and fish and wildlife propagation would also be purposes of the project. Preliminary estimates suggest that water in the reservoir can be made available to industry at a cost of around 1.4 cents per 1,000 gallons. This price should be attractive to industry and there is good reason to believe that the second stage of construction which would make available an additional amount of approximately 25,000 acre-feet of water per year can be financed with water revenues before 1980. Legislation (S. 487, 86th Cong., Senator Dennis Chavez) has been introduced which would provide for a Federal contribution to construction costs of the reservoir in recognition of flood and sediment control, recreation, and fish and wildlife benefits. It is anticipated that the recreation and fish and wildlife benefits particularly will be substantial. Project plans, when developed, will be carefully coordinated with appropriate Federal agencies. The advice and consultation of experts from these agencies is being utilized in the planning stages.

GROUND WATER

The use of ground water for irrigation in the State of New Mexico has developed rapidly in the past 20 years. In 1940 an estimated 140,000 acres were irrigated with ground water; in 1950 an estimated 320,000 acres; and in 1955 an estimated 588,000 acres. In 1955 approximately 1,260,000 acre-feet of ground water was pumped for irrigation and about 105,000 acre-feet was pumped for municipal and industrial purposes. An additional 13,000 acre-feet was pumped for rural uses other than irrigation. In 1955, according to Geological Survey estimates, 90 percent of the municipal and industrial requirements of the State were met with ground water.

The locations of all large supplies of ground water in New Mexico are generally believed to be known and an increase in ground-water usage in the next 20 years comparable with that of the last 20 years cannot be predicted.

In the declared Animas, Mimbres, Playas, Portales, Lea County, and Estancia Basins, as well as in other areas of intensive ground-water irrigation, water is being withdrawn primarily from storage, and water levels will continue to decline. The time limit for irrigation in the House, Clovis, Portales, northern Lea County, and Causey-Lingo areas on the southern High Plains and in the Estancia Valley in central New Mexico is set by the thickness of the saturated aquifer, whereas the thickness of the aquifer in most of the Animas, Mimbres, and Playas Basins is so great that pumping costs will probably limit withdrawals of water for agriculture long before the water supply is actually exhausted. The policy of the State is, insofar as is possible, to limit withdrawals in these areas to that which can be sustained for a reasonable payout period, usually about 40 years.

It is desirable, of course, that the ground-water resources be available to future generations in perpetuity; however, the mining of water can be justified as readily as the mining of any of our other mineral resources such as uranium, oil, or coal. It is not practical to operate a ground water basin on a continuous-yield basis when the amount of water in storage is very large compared with the average annual recharge. An example is the Lea County Basin in southeastern New Mexico where the average annual recharge is 29,000 acre-feet per year and the permitted withdrawals will average about 440,000 acre-feet per year. The great value of the approximately 27 million acre-feet in storage in the basin when pumping began can be realized only by mining. Furthermore, to justify the marketing, storage, and transportation facilities essential to a competent agricultural economy in the area it is necessary for the withdrawals to exceed the recharge.

While it is possible to justify the mining of ground-water resources, the practice will make it necessary to face serious water-supply problems in the future. In some instances it will be possible to meet these problems only by complete readjustment of the economy of the area. While long-range predictions of the value of water in various uses are dangerous, it appears likely that it will not be, in general, economically feasible to import water over appreciable distances for agricultural purposes when the local ground-water resources have been mined out. However, when reduced well yields or excessive lifts make pumping for agricultural purposes uneconomic, the residual water may well supply the municipal and industrial needs of a vigorous nonagricultural economy for many years.

In Lea County pumping for irrigation will probably be uneconomic when about two-thirds of the aquifer is dewatered. At that time there will probably remain substantial valuable reserves of oil and gas in the area. To produce and process those reserves it will be necessary to use numerous low-production wells to pump the residual fresh water, and it may also be necessary to desalinize the abundant brackish waters and brines that occur in the area.

It is estimated that by 1965 it will become impractical to produce water from existing wells for the irrigation of about 19,000 acres of the total of 51,000 acres now being irrigated in the Portales Basin. The Interstate Stream Commission is presently studying a project which would supply water for about 20,000 acres in the most heavily pumped area in the vicinity of the city of Portales. The project would consist of a well field constructed in a sandhill area under which the ground-water reservoir has not as yet been developed, and conveyance works about [illegible] miles in length which would carry the water to the lands under which the ground-water reservoir will have been exhausted. Preliminary studies show that the water supply for the project is assured for more than 40 years.

There appears to be a possibility that this project will qualify for Federal assistance under reclamation law. Particular importance is attached to this project because it may point the way to a solution to many ground-water problems in the West and possibly in other areas where irrigation with ground water is practiced.

In most of the basins in the State where ground waters are intimately related to surface waters, the practice of using ground water to supplement surface-water supplies has been encouraged and well developed, notably in the Carlsbad, Virden Valley, Hondo, Penasco, Bluewater, and Rio Grande Basins. This practice is generally encouraged because it makes good economic use of ground-water storage, which is depleted during periods of drought and replenished in periods of good surface-water supply. Further development of this practice is anticipated, particularly in the Middle Valley of the Rio Grande. Thus far the development of supplemental supplies for irrigation has been accomplished on an individual basis, but the New Mexico Interstate Stream Commission and the Bureau of Reclamation are studying possibilities for the rejuvenation and rehabilitation of small projects by developing supplemental ground water on a project basis.

The Roswell artesian basin is susceptible to operation on a continuous yield basis but the present withdrawal of about 440,000 acre-feet per year amounts to about 190 percent of the currently estimated safe yield. This amount of water is the total withdrawn from the artesian and shallow aquifers for the irrigation of about 132,000 acres and for municipal-industrial use in the area. This apparent overdraft coupled with protracted drought has resulted in serious conditions in terms of artesian head lowering, salt encroachment in the artesian aquifer, and depletion of water in storage in the shallow-water aquifer.

A water rights adjudication suit now before the court may reduce the total irrigated acreage by 10,000 to 15,000 acres. The Pecos Valley Artesian Conservancy District is giving consideration to the purchase and drying up of valid ground-water rights to reduce the annual withdrawals. Also, Federal, State, and local interests are cooperatively studying possibilities for artificial recharge or water-salvage measures that might be employed without impairing existing surface-water rights. While some reduction in irrigated acreage may be necessary, the average annual recharge to the basin is adequate to sustain a strong agricultural economy in the area.

Present knowledge indicates that in most areas of intensive ground-water usage in the State pumpage can be continued at present rates well beyond 1980. Exceptions are the Portales Valley and localized marginal areas. In some areas the annual withdrawals may be substantially increased.

GENERAL

Future municipal and industrial needs

Exhibit 1 sets forth the projected population of the State by counties through 1980, and exhibit 2 presents data reflecting the State's adjustment from an agricultural to an urban economy. These data show that it will be necessary to put increasing amounts of water to municipal and industrial use to meet the needs of this changing economy. The water-resource development plans described above can meet these needs through 1980 in the San Juan, Rio Grande, and lower Canadian River Basins in New Mexico. Also, with an equitable apportionment of the waters of the Lower Colorado River system in the decree in *Arizona* v. *California*, the municipal and industrial needs in the area drained by the Lower Colorado River tributaries in New Mexico can probably be met.

In other areas of the State growing municipal and industrial needs can be met by acquiring water rights presently being exercised for irrigation. New Mexico statutes permit the change of point of diversion and change of place and method of use of water rights if such changes will not impair other existing rights to the use of water. Both municipalities and counties have the power under New Mexico law to condemn water rights for public purposes.

At the present time about 93 percent of all water diverted in New Mexico is used for irrigation. Most of the balance of 7 percent is used for municipal and industrial purposes. Only minor amounts are directly chargeable to recreation, fish and wildlife propagation, stock, and nonagricultural rural use. Thus, it can be seen that municipal and industrial usage could be doubled by a reduction of only about 7.5 percent in the amount of water used in the agricultural economy of the State.

Because of the high value of water in municipal and industrial uses, water for such purposes can be transported relatively great distances. Therefore, the future centers of population and industry may be determined as much by the location of other natural resources, transportation, and labor as by the natural occurrence of water. In those instances where elaborate and extensive works are necessary to being the water to a point of municipal use, Federal planning assistance under programs such as the Housing and Home Finance Agency program (Public Law 560, 83d Cong.) may be necessary. Attached is a copy of a letter from the acting State planning officer setting forth his views on the nature of the planning program that should be undertaken in connection with the development and utilization of the State's water resources. Also attached is a letter from the President of the University of New Mexico setting forth his views on meeting the water needs of the State's changing economy.

Recreation

There is a growing recognition of the esthetic and economic value of water applied to the purposes of recreation and fish and wildlife propagation. New Mexico law recognizes these as beneficial uses. The New Mexico Department of Game and Fish has already acquired irrigation water rights for a number of small impoundments for fish and wildlife propagation, transferring the water rights acquired to these uses under State law. Pittman-Robertson and Dingell-Johnson Act funds facilitate the development of such desirable water usage. The attached letter of September 3, 1959, from the director of the department of game and fish indicates that additional amounts of water will be required for the department's program in the future, and the attached letter of September 15, 1959, from the superintendent of the State park commission indicates need for additional water for recreation purposes.

Phreatophytes

One of the most serious water-resource problems facing New Mexico and other States of the West is the large, rapidly increasing depletion of water supply by nonbeneficial plant growth in and along the streams. This problem is related to sedimentation in that sediment deposits provide a favorable breeding ground for such plants. Water lost to such plants in New Mexico is variously estimated from 500,000 acre-feet to more than 850,000 acre-feet per year. This problem is of such magnitude that Federal assistance in studying and carrying out corrective measures will probably be required to prevent disaster. Furthermore, local financing is generally impractical because the beneficiaries of most water-salvage programs are not readily identifiable. The water salvaged is used by numerous individual as well as corporate diverters.

New Mexico's experience with this problem leads to the conclusion that additional basic research in the techniques for the eradication and control of the plants and other methods of salvaging water from them is needed.

Desalinization

Work done to date by the Department of the Interior's Office of Saline Water gives good reason to hope that techniques for the desalinization of brackish waters and brines can materially enhance the water resources of New Mexico. These techniques can be employed to improve the usefulness of present supplies. Table 7 attached hereto sets forth the quality of water being used in 16 communities in New Mexico whose water supply is below the standards set by the U.S. Public Health Service.

Desalinization techniques can also be employed to make usable abundant brackish water resources presently unsuited for agricultural, domestic, or industrial use. It is estimated that there is in underground storage in the Tularosa Basin alone as much as 143 million acre-feet of brackish water. Continued and accelerated Federal research in desalinization techniques can make important contributions to the Nation's water resources.

The 1959 session of the New Mexico Legislature authorized the expenditure of up to $100,000 of State funds to cooperate with the Federal Government in the construction of a demonstration plant for the conversion of brackish water in New Mexico. The construction and operation of such a plant in New Mexico would provide a proving ground for the techniques which have thus far been developed from the research program of the Office of Saline Water. Attached hereto is a letter dated September 19, 1959, setting forth the views of the Director of the Institute of Scientific Research of the New Mexico Highlands University.

Department of Agriculture

The Department of Agriculture's small watersheds program (Public Law 566, 83d Cong.) has been well accepted in New Mexico. This program can make important contributions to water resources in New Mexico through flood and sediment control and improved water usage. Sediment retention will contribute to the control and reduction of water usage in the stream systems by nonbeneficial plants. Table 8 shows the status of the program in New Mexico. The program has been characterized by close cooperation with the State and strict compliance with State water laws.

While there is little doubt of the value of the small watersheds program, there is a serious lack of information concerning the net effects of the work on water supply. Such information is badly needed not only for the design of the watersheds projects, but also for the design and planning of other water-resources projects.

Land leveling and ditch lining under the Department of Agriculture's agricultural conservation program is potentially important to water conservation. Thus far 300,000 acres have been leveled under this program, and about 1,400 miles of canals and ditches have been lined. The administrator of the program in New Mexico estimates that an additional 350,000 acres should be leveled and an estimated additional 1,300 miles of canals and ditches should be lined in the period to 1975 to improve water usage. The New Mexico Interstate Stream Commission has supplemented this program by lending $50,000 to the Pecos Valley Artesian Conservancy District to be loaned to individual farmers at low interest rates for the installation of conservation practices on their lands. The commission is prepared to lend additional amounts from Ferguson Act funds to other agencies authorized to enter loan contracts. Expansion of the agricultural conservation program would, by conservation, materially increase the total amount of water available for beneficial use.

To make the most conservative use of irrigation water there is a great need for additional information concerning irrigation management, including consumptive use and required duty of water for the various crops, soils, and climates of the State, and for the dissemination of such information to the farmers. It is suggested that the Department of Agriculture should cooperate with the State university in an accelerated program to produce the required information.

Attached are letters from the president of New Mexico State university and the president of the New Mexico Association of Soil Conservation Districts setting forth their views on water-resources development and utilization in the State.

Vegetational management

Research on vegetational management on watersheds in Colorado and Arizona (9, 10) suggests that this technique might result in important increases in water yield. Further research in the field is justified and should be accelerated. Legislation such as proposed Wilderness Acts (e.g., S. 1123, 86th Cong.) which would prevent such vegetation management on large, important watersheds should be avoided.

Weather modification

While there appears to be some statistical evidence ([illegible]) that precipitation can be increased by cloud-seeding techniques in coastal orographic situations, the value of these techniques in semiarid regions is still highly speculative. The potentialities justify intensification of research in this field with the objective of a clearer understanding of the basic processes of formation and precipitation of clouds and thermodynamic effects of those processes. Present knowledge does not permit the application of known techniques for inducing precipitation with sufficient precision to insure that precipitation is not reduced or adversely redistributed. The complexity of this problem is such that it would appear unwise to place any reliance on induced precipitation for a significant contribution to increased water resources prior to 1980.

Evaporation reduction and seepage control

Research to date on the use of monomolecular films to reduce evaporation from reservoirs shows considerable promise (12), and research in this field should be accelerated. Results indicate that the technique may be applicable to small reservoirs in the very near future, yielding great benefits to stockmen and others.

Basic data

Basic data are essential to orderly programs of water-resource investigation and development. In New Mexico there are about 14 million acres of land requiring survey or resurvey to reestablish deteriorated markers for cadastral mapping. Adequate topographic maps are available for only about 26 million acres or 33 percent of the total area of the State. The mapping programs of the Bureau of Land Management and U.S. Geological Survey should be accelerated to provide the cadastral, topographic, and geologic mapping necessary for water-resources development and other purposes. The New Mexico Mapping Advisory Committee is attempting to coordinate the activities of various agencies engaged in mapping and to establish mapping priorities.

New Mexico has steadily increased its contributions to the cooperative basic-data collection programs of the surface water, quality of water, and ground water branches of the U.S. Geological Survey. Despite these increased cooperative contributions there has been little increase in the scope of the surface water and quality of water programs because of increasing costs and because it has been necessary for the State to contribute to the cost of operating certain quality-of-water stations which were formerly operated under all-Federal financing. All-Federal financing of basic-data stations should be maintained at the highest practical level to permit increasing State contributions to be used in the expansion of the program.

The density of the U.S. Weather Bureau reporting stations should be increased to provide adequate climatologic data.

Attached hereto is a letter of September 14, 1959, from the president of the New Mexico

Institute of Mining and Technology setting forth his views concerning needed basic water-resources research programs.

Project investigations

Both the Bureau of Reclamation and the Corps of Engineers have described in detail comprehensive programs of investigation including many studies not mentioned above. The State has been consulted in the development of these programs and approves them as an essential part of the approach in meeting the water-resource problems that will be encountered prior to 1980 (5, 13).

The 1955 session of the New Mexico Legislature enacted a law designed to meet a statewide need for the conservation and more efficient use of water. This act created the New Mexico irrigation works construction fund and authorized the interstate stream commission to issue revenue bonds for the purpose of constructing projects for the conservation and development of water. This program and activities under it are described in detail in the 23d biennial report of the State engineer. Some of the activities under the program are described in this statement, but a copy of the biennial report is forwarded herewith as a convenient reference for the committee in the event that additional detail concerning the program would be helpful. Also, it is respectfully suggested that other information in this report might be useful in the consideration of the water problems of the State of New Mexico.

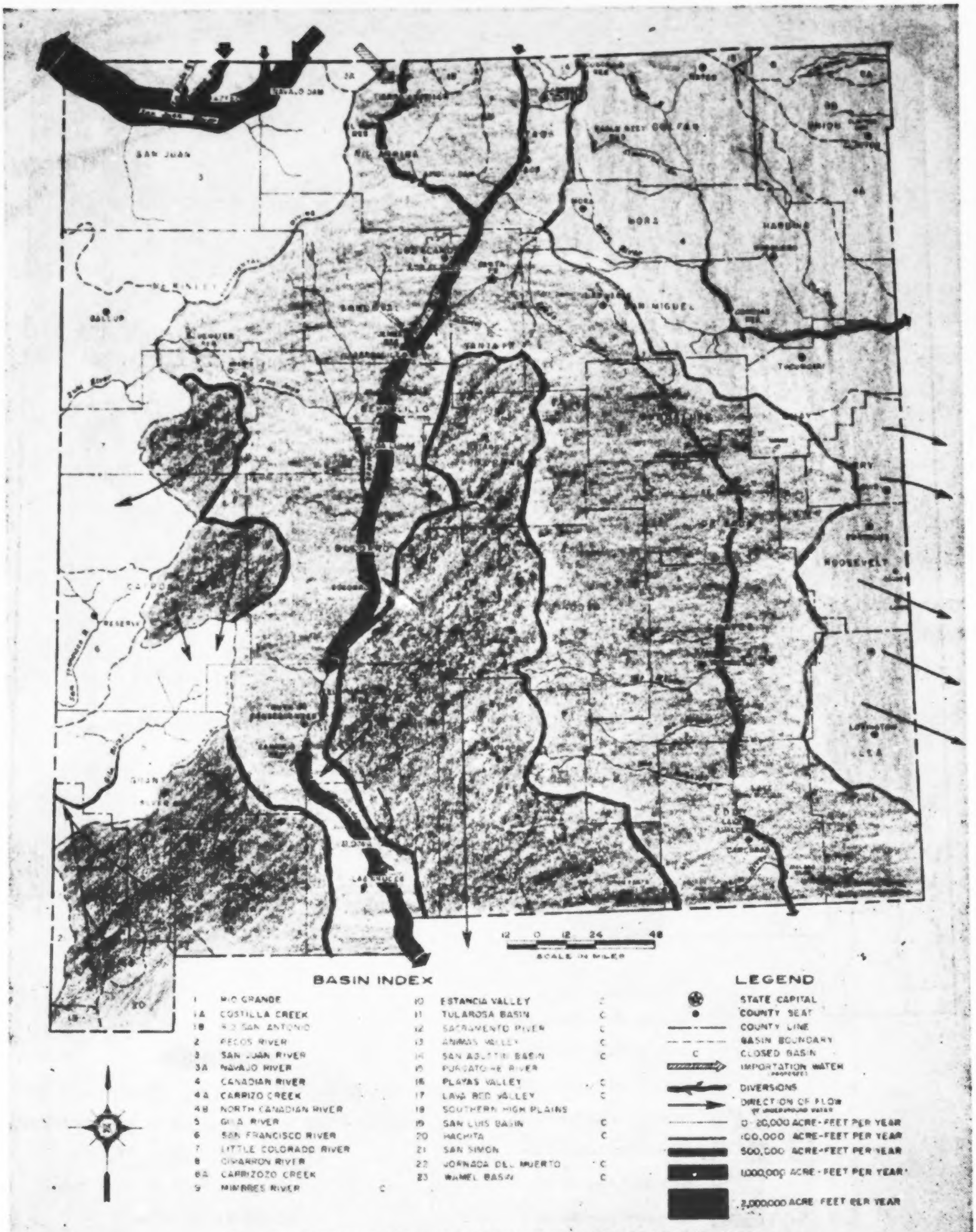
SAN JUAN
NAVAJO DAM
MORA
SAN MIGUEL
HARDING
UNION
SANTA FE
BERNALILLO
GALLUP
RESERVE
GRANT
ROOSEVELT
LOVINGTON
LEA
LAS CRUCES
CARLSBAD
TUCUMCARI
12 0 12 24 48
SCALE IN MILES
BASIN INDEX
1 RIO GRANDE
1A COSTILLA CREEK
1B RIO SAN ANTONIO
2 PECOS RIVER
3 SAN JUAN RIVER
3A NAVAJO RIVER
4 CANADIAN RIVER
4A CARRIZO CREEK
4B NORTH CANADIAN RIVER
5 GILA RIVER
6 SAN FRANCISCO RIVER
7 LITTLE COLORADO RIVER
8 CIMARRON RIVER
8A CARRIZOZO CREEK
9 MIMBRES RIVER C
10 ESTANCIA VALLEY C
11 TULAROSA BASIN C
12 SACRAMENTO RIVER C
13 ANIMAS VALLEY C
14 SAN AGUSTIN BASIN C
15 PURGATOIRE RIVER
16 PLAYAS VALLEY C
17 LAVA BED VALLEY C
18 SOUTHERN HIGH PLAINS
19 SAN LUIS BASIN C
20 HACHITA C
21 SAN SIMON
22 JORNADA DEL MUERTO C
23 WAMEL BASIN C
LEGEND
STATE CAPITAL
COUNTY SEAT
COUNTY LINE
BASIN BOUNDARY
C CLOSED BASIN
IMPORTATION WATER (PROPOSED)
DIVERSIONS
DIRECTION OF FLOW OF UNDERGROUND WATER
0-20,000 ACRE-FEET PER YEAR
100,000 ACRE-FEET PER YEAR
500,000 ACRE-FEET PER YEAR
1,000,000 ACRE-FEET PER YEAR
2,000,000 ACRE-FEET PER YEAR

FIG. I – DRAINAGE BASINS AND STREAM FLOW MAP OF NEW MEXICO

Reproduced from best available copy.

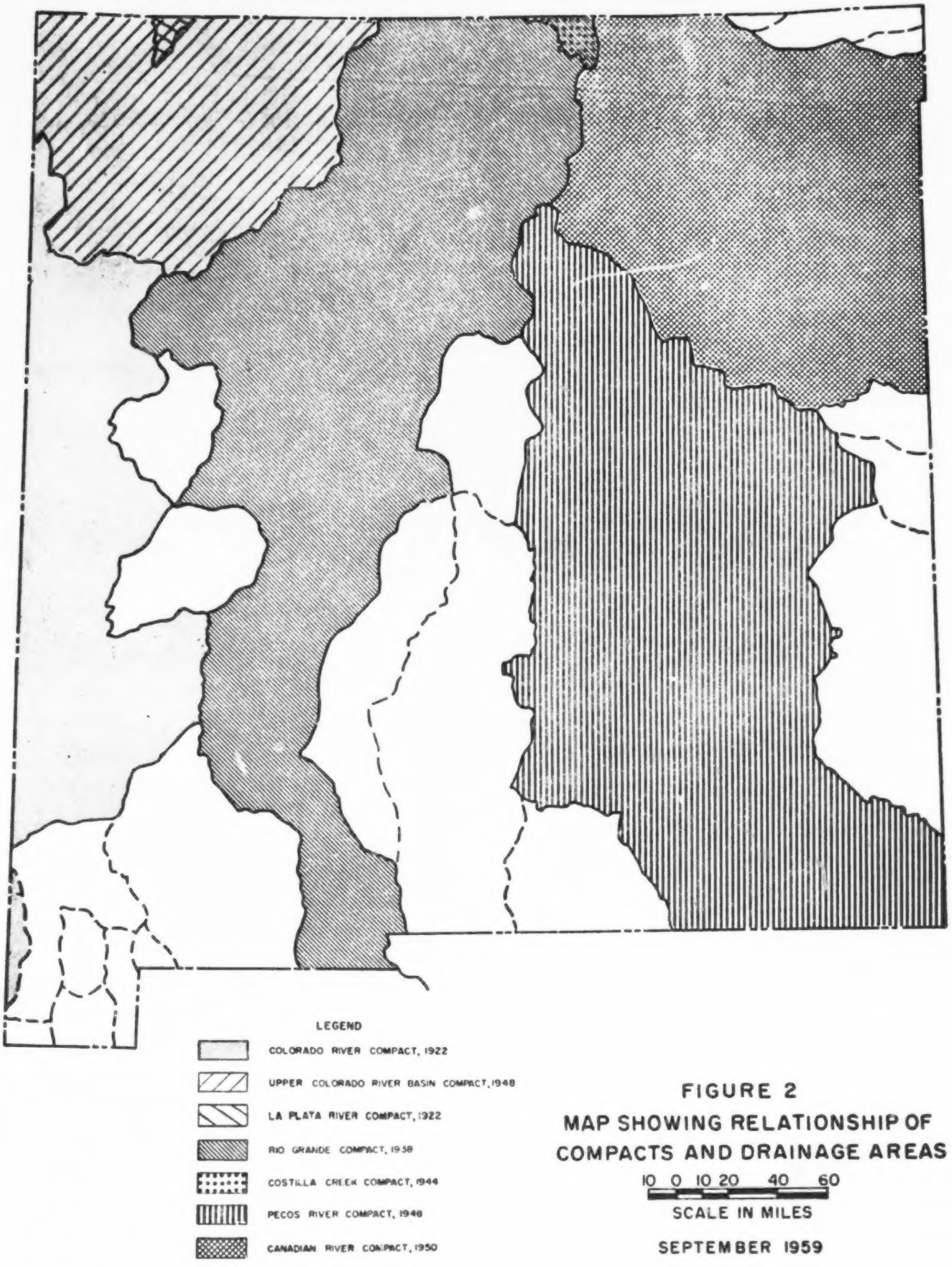
LEGEND
COLORADO RIVER COMPACT, 1922
UPPER COLORADO RIVER BASIN COMPACT, 1948
LA PLATA RIVER COMPACT, 1922
RIO GRANDE COMPACT, 1938
COSTILLA CREEK COMPACT, 1944
PECOS RIVER COMPACT, 1948
CANADIAN RIVER COMPACT, 1950
10 0 10 20 40 60
SCALE IN MILES

FIGURE 2
MAP SHOWING RELATIONSHIP OF COMPACTS AND DRAINAGE AREAS

SEPTEMBER 1959

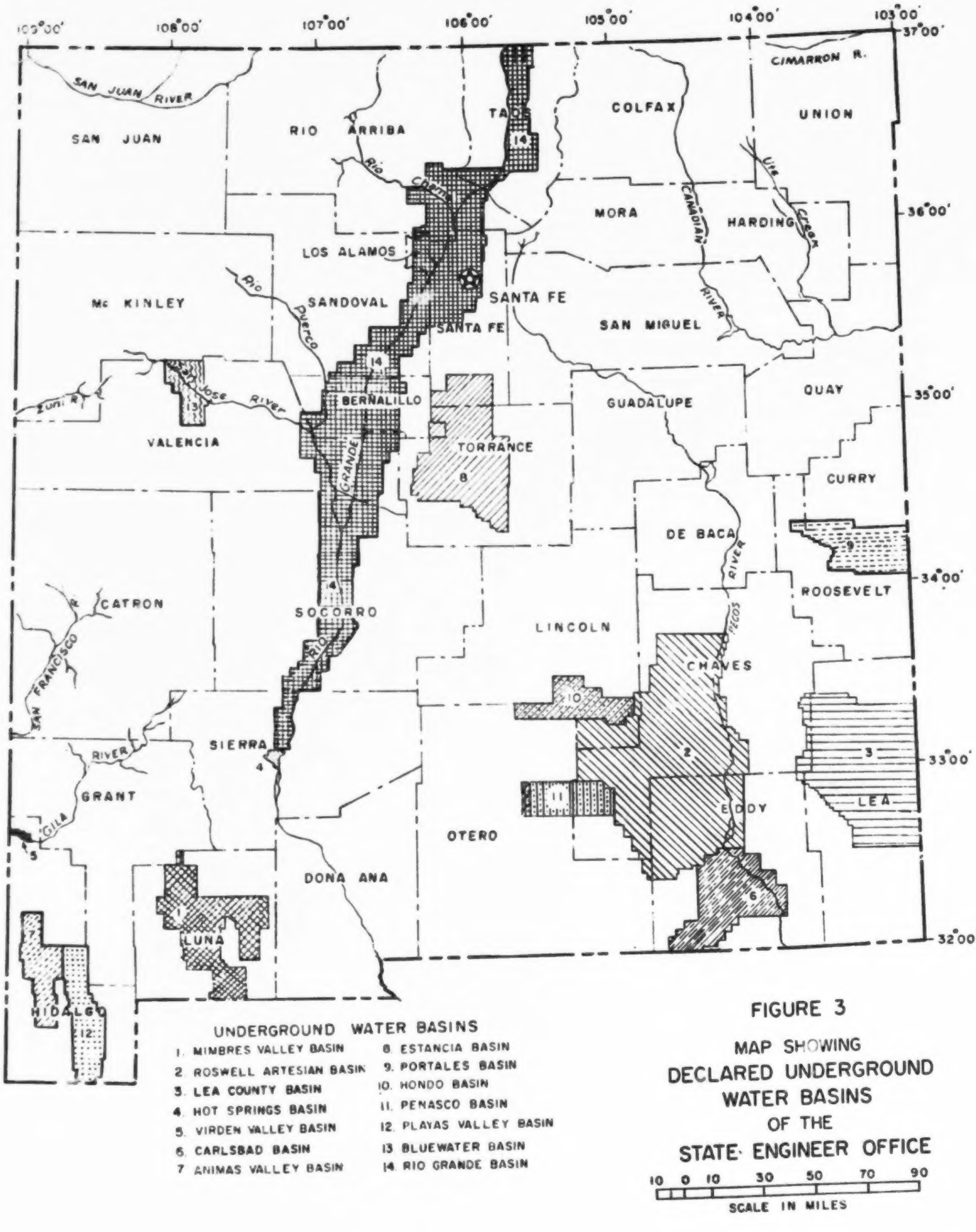
109°00'
108°00'
107°00'
106°00'
105°00'
104°00'
103°00'
37°00'
36°00'
35°00'
34°00'
33°00'
32°00'
SAN JUAN RIVER
CIMARRON R.
SAN JUAN
RIO ARRIBA
TAOS
14
COLFAX
UNION
Rio Chama
Ute Creek
MORA
CANADIAN RIVER
HARDING
LOS ALAMOS
Rio Puerco
Mc KINLEY
SANDOVAL
SANTA FE
SANTA FE
SAN MIGUEL
14
Zuni R.
San Jose River
13
BERNALILLO
QUAY
GUADALUPE
VALENCIA
TORRANCE
8
RIO GRANDE
CURRY
DE BACA
9
RIVER
ROOSEVELT
4
CATRON
SOCORRO
LINCOLN
RIO
PECOS
CHAVES
SAN FRANCISCO
10
SIERRA
4
2
3
GILA
RIVER
GRANT
11
EDDY
LEA
5
OTERO
1
DONA ANA
6
7
LUNA
HIDALGO
12
UNDERGROUND WATER BASINS
1. MIMBRES VALLEY BASIN
2. ROSWELL ARTESIAN BASIN
3. LEA COUNTY BASIN
4. HOT SPRINGS BASIN
5. VIRDEN VALLEY BASIN
6. CARLSBAD BASIN
7. ANIMAS VALLEY BASIN
8. ESTANCIA BASIN
9. PORTALES BASIN
10. HONDO BASIN
11. PENASCO BASIN
12. PLAYAS VALLEY BASIN
13. BLUEWATER BASIN
14. RIO GRANDE BASIN
10 0 10 30 50 70 90
SCALE IN MILES

FIGURE 3

MAP SHOWING
DECLARED UNDERGROUND
WATER BASINS
OF THE
STATE ENGINEER OFFICE

TABLE 1.—*Surface water of New Mexico* [1]

[Units: 1,000 acre-feet]

River basin	Inflow to State	New Mexico water yield	Acres irrigated	Estimated depletions					Outflow from State	Stream-flow period	Index to 1930–56 stream flow	Applicable compact
				Irrigaton	Municipal and industral	Reservoir evaporation	Non-beneficial	Total				
San Juan	2,110.9	264.4	50,100	[2] 78.6	1.0	---------	[3] 107.2	186.8	2,195.8	1914–45	0.78	Colorado River, La Plata River, Upper Colorado River.
Little Colorado	---------	[4] 51.0	8,800	[2,4] 6.0	---------	[4] 5.9	[3,4] 2.6	14.5	[4] 34.0	1930–56	1.00	Colorado River.
Gila	[4,5] 2.5	[6] 177.7	10,800	[2] 16.0	0	---------	[3,4] 2.6	18.6	[5] 161.7	1931–40	.94	Do.
Rio Grande	448.0	1,474.9	262,000	[7] 447.7	[8] 2.8	[9] 254.8	[10] 569.7	1,275.0	647.9	1890–1935	.82	Rio Grande.
Pecos	0	578.6	[4] 66,100	[2] 171.1	9.5	[11] 27.2	131.8	339.6	239.0	1905–48	.90	Pecos River.
Canadian	---------	[4,12] 450.0	102,900	[2,13] 192.8	7.0	[4] 44.0	[3,4,14] 20.0	263.8	[13] 184.2	1920–47	.85	Canadian River.
Cimarron	---------	44.0	7,000	10.0	0	---------	---------	10.0	[4] 33.0	1920–43	.90	None.
Total	2,561.4	3,040.6	507,700	922.2	20.3	331.9	833.9	2,108.3	3,495.6	---------	---------	

[1] Source: Basis for formulating a water resources program for New Mexico, U.S. Bureau of Reclamation, September 1950.

[2] Includes depletions incidental to irrigation. The figures presented are not corrected for the effects of ground-water pumpage on surface-water supply.

[3] Channel losses only.

[4] Estimate supplied by New Mexico Interstate Stream Commission to complete tabulation.

[5] Does not include San Simon Valley or San Francisco River below Glenwood.

[6] Does not include channel losses above Blue Creek and Glenwood.

[7] Does not include depletions incidental to irrigation.

[8] City of Santa Fe.

[9] Elephant Butte and Caballo Reservoirs only.

[10] Includes depletions incidental to irrigation.

[11] Alamogordo, McMillan, and Avalon Reservoirs only.

[12] Does not include water production below Logan nor the North Canadian River in New Mexico.

[13] Bureau estimate adjusted for reservoir evaporation.

[14] Above Logan only.

TABLE 2.—*Estimated use of ground water in New Mexico, 1955*

[All data supplied by USGS except those marked (*) which are supplied by the New Mexico State engineer office]

Area	Irrigated area (acres)		Irrigation diversions (acre-feet)		Total irrigation diversions	Other diversions (acre-feet)		Total diversions (acre-feet)
	Ground water only	Ground water to supplement surface water	Ground water only	Ground water to supplement surface water		Municipal and industrial	Rural nonagricultural	
Statewide	443,020	144,670	967,140	294,520	1,261,660	104,890	13,010	1,379,560
Arkansas River Basin: [1]								
Union County	4,370		8,000		8,000	500		8,500
Other areas						1,880		1,880
Basinwide (rural)							650	650
Basin total	4,370		8,000		8,000	2,380	650	11,030
Colorado River Basin: [2]								
San Simon Valley	*2,400	*500	*6,000	*500	*6,500			6,500
Virden Valley underground water basin	*460	*2,870	*1,380	*4,300	*5,680			5,680
Upper Gila River Valley and tributaries		*2,290		*2,290	*2,290			2,290
Other areas		*500		*500	*500	3,990		4,490
Basinwide (rural)							3,200	3,200
Basin total	2,860	6,160	7,380	7,590	14,970	3,990	3,200	22,160
Closed basins: [3]								
Animas Valley underground water basin	11,400		19,800		19,800			19,800
Crow Flats area	3,000		*10,000		*10,000			10,000
Estancia underground water basin	25,000		36,000		36,000	250		36,250
Mimbres Valley underground water basin	33,500		84,000		84,000	2,700		86,700
Playas Valley underground water basin	1,270		2,200		2,200			2,200
Tularosa Basin	3,000	2,200	*9,000	*2,200	*11,200	4,290		15,490
Upper Mimbres River Valley		1,000	*1,000					1,000
Basinwide (rural)							2,570	2,570
Basin total	77,170	3,200	162,000	2,200	164,200	7,240	2,570	174,010
Pecos River Basin: [4]								
Carlsbad underground water basin	4,220	20,000	13,000	14,500	27,500	9,080		36,580
Hondo underground water basin	350	2,900	*700	*2,900	*3,600			3,600
Penasco underground water basin		1,000		*1,000	*1,000			1,000
Roswell artesian underground water basin	120,100	11,680	*396,600	*19,300	415,900			415,900
Other areas						500		500
Basinwide (rural)							1,290	1,290
Basin total	124,670	35,580	410,300	37,700	448,000	9,580	1,290	458,870
Rio Grande Basin: [5]								
Bluewater underground water basin		5,000		11,500	11,500	1,560		13,060
Hot Springs underground water basin	*120	*330	*360	*330	*690	560		1,250
Rio Grande Valley below Elephant Butte Reservoir	*4,400	86,400	*13,200	*223,200	*236,400	2,870		239,270
Rio Grande underground water basin (above Elephant Butte)	2,100	8,000	3,500	*12,000	*15,500	47,100		62,600
Sierra County	1,000		*2,000		*2,000			2,000
Other areas						9,310		9,310
Basinwide (rural)							4,430	4,430
Basin total	7,620	99,730	19,060	247,030	266,090	61,400	4,430	331,920
Southern High Plains: [6]								
Causey-Lingo area	5,000		10,000		10,000			10,000
Clovis area	74,000		80,000		80,000	3,800		83,800
House area	3,580		5,400		5,400			5,400
Lea County underground water basin	93,000		170,000		170,000	9,140		179,140
Portales underground water basin	50,750		95,000		95,000	1,200		96,200
Southern Lea County						6,1[illegible]		6,160
Basinwide (rural)							870	870
Basin total	226,330		360,400		360,400	30,300	870	361,570

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[1] Ground water generally is available only in small quantities from wells and much is unsuitable for domestic or municipal use. General investigations of the ground-water resources have been made in only parts of the basin. Investigations of the rest of the basin are needed to indicate areas where well yields and water quality will be suitable for development of supplies for municipalities and industries requiring small to moderate quantities of water.

[2] Relatively large ground-water supplies are not known to occur except in the Gila River drainage basin. General ground-water investigations of the entire basin are needed to indicate availability of water supplies.

[3] Principally ground-water mining. Except in Estancia Valley, the aquifers reach thicknesses of from more than 1,000 to several thousand feet. Recharge is only a small percent of total precipitation but underground storage is great. Economic life of irrigation developments probably will be limited by cost of pumping rather than by availability of water. Movement of brackish and saline waters into presently fresh-water areas may cause problems in the Tularosa Basin.

[4] Substantial recharge to principal aquifers. However, current ground-water use in Roswell artesian underground water basin exceeds estimated average annual recharge. Movement of saline water into fresh-water zones of aquifers near Roswell is creating a serious situation. Continuing water-level observations, water-use information, and chemical quality records are needed to suggest remedial action.

[5] Largest ground-water use is to supplement surface-water supplies. Rio Grande underground water basin administration recognizes intimate interrelationship of ground- and surface-water supplies and is designed to permit fullest possible use of the ground-water reservoir without impairment of existing water rights. Some problems of pollution of fresh-water supplies with uranium mill wastes have arisen in Bluewater underground water basin and Ambrosia Lake area to north.

[6] No perennial streams; recharge to ground-water reservoirs is small percentage of precipitation. Ground water is being mined in all areas. Economic life of agricultural developments limited due to relatively thin aquifers. Economy of areas may be maintained for longer time by adjustment from irrigated agriculture to urban-industrial activities and readjustment to dry farming and stock raising. Irrigation economy of Portales Valley underground water basin may be extended by transportation of water from nearby undeveloped areas. Continuing measurements of water levels in wells and estimates of ground-water use are needed for administration and planning. Some problems of pollution of fresh-water supplies with oil-field wastes are being dealt with.

Table 3.—*Projections of New Mexico population by drainage areas—1940–80*

Area	1940	1959	1965	1980
San Juan River Basin	25, 115	69, 650	104, 500	238, 700
Lower Colorado River Basin [1]	23, 802	40, 500	51, 800	99, 900
Southwestern closed drainage basins [2]	28, 828	32, 650	37, 550	52, 300
Rio Grande Basin [3]	225, 355	465, 650	621, 900	1, 135, 550
Estancia Valley	9, 056	5, 300	6, 400	10, 200
Tularosa Basin	11, 067	57, 900	83, 700	157, 450
Sacramento Basin	274	250	350	500
Arkansas River Basin [4]	57, 153	40, 600	46, 100	65, 700
Pecos River Basin	102, 467	160, 350	193, 350	301, 800
Southern High Plains	48, 701	90, 750	111, 550	194, 600
Total, State	531, 818	963, 600	1, 257, 200	2, 256, 700

[1] Includes Puerco River, Zuni River, San Francisco River, Gila River, and San Simon Basin, and part of lava bed basin, a closed surface-drainage which discharges some water to the Colorado River.

[2] Includes Animas, Hachita, Mimbres, Playas, San Luis, and Wamel Valleys.

[3] Includes Jornada del Muerto closed drainage area which discharges ground water to the Rio Grande.

[4] Includes Canadian River.

Source: Data for year 1940 are based on information from the Bureau of the Census. Estimates for years 1959, 1965, and 1980 are based on data from "Tentative Projections of Population of New Mexico Counties," prepared in 1959 by the Bureau of Business Research of the University of New Mexico, submitted as exhibit 1.

Table 4.—*Projections of population and water requirements of Albuquerque metropolitan area (Bernalillo County), 1956–80*

Year	Population	Total diversion	
		Million gallons per day	1,000 acre-feet per year
1956	220, 000	47	53
1960	264, 000	58	65
1965	354, 500	81	91
1970	463, 600	109	122
1980	672, 200	168	188

Table 5.—*Upper Colorado River water available for use in New Mexico average annual stream depletion at sites of use*

[In thousand acre-feet]

New Mexico entitlement for planning purposes	838. 0
Committed uses by present and authorized projects:	
Present uses	92. 3
Share of evaporation losses from mainstem reservoirs [1]	73. 3
Hammond project	6. 8
Extension of Indian projects [2]	24. 7
Navajo Reservoir losses [3]	39. 0
Utah Construction Co.[2]	39. 0
Total committed uses	275. 1
Available for proposed and future developments	562. 9
Proposed in coordinated report:	
Navajo irrigation project [4]	252. 3
San Juan-Chama project (initial stage)	110. 0
Total proposed	362. 3
Available for future developments	200. 6
Municipal and industrial water from Navajo Dam [5]	112. 5
Balance	88. 1
Estimated additional reservoir losses—ultimate upper basin reservoirs	34. 7
Balance	53. 4
Proposed Animas-La Plata project—New Mexico lands	33. 4
Remainder	20. 0

[1] 11¼ percent of 652,000 acre-feet. Represents estimated depletion due to evaporation losses from Glen Canyon, Flaming Gorge, and Curecanti storage units. See p. 11 "Financial and Economic Analysis," Colorado River storage project and participating projects, February 1958.

[2] Not a unit of the Colorado River storage project.

[3] P. 11, "Financial and Economic Analysis," Colorado River storage project and participating projects, February 1958.

[4] P. 8, Navajo project, New Mexico, supplemental report, March 1957.

[5] Estimated depletion by the diversion of 225,000 acre-feet per year for municipal and industrial uses.

Table 6.—*Summary of New Mexico's present and potential annual uses of water from the Lower Colorado River tributaries*

[Units: 1,000 acre-feet]

Stream	Present uses					Potential uses		Total ultimate use	
	Irrigated area	Depletion							
		At site			At New Mexico-Arizona State line				
		Surface water	Ground water	Total		At site	At New Mexico-Arizona State line	At site	At New Mexico-Arizona State line
	Acres								
Black Creek	598	2. 4	0	2. 4	2. 4	1. 3	1. 3	3. 7	3. 7
Rio Puerco	1, 384	2. 6	1. 1	3. 7	1. 6	7. 3	7. 3	11. 0	8. 9
Zuni River	7, 445	14. 1	0	14. 1	8. 3	3. 7	3. 7	17. 8	12. 0
Carrizo Creek	0	0	0	0	0	2. 0	1. 5	2. 0	1. 5
Little Colorado River	0	0	0	0	0	1. 8	1. 8	1. 8	1. 8
San Francisco River	5, 018	6. 0	0	6. 0	3. 8	5. 4	5. 4	11. 4	9. 2
Gila River	11, 121	19. 7	1. 9	21. 6	8. 7	32. 7	32. 7	54. 3	41. 4
San Simon Creek	2, 900	1. 4	5. 8	7. 2	3. 4	2. 5	0	9. 7	3. 4
Total	28, 466	46. 2	8. 8	55. 0	28. 2	56. 7	53. 7	111. 7	81. 9

TABLE 7.—*New Mexico communities of over 1,000 population using substandard water for public supply*

Community and county [1]	Population (1958 estimate)	Economy	Water supply [2]				
			Chloride (parts per million)	Sulfate (parts per million)	Other (parts per million) [3]	Total dissolved solids (parts per million)	Source
Espanola, Rio Arriba	1,850	Farming, ranching			F 1-2.06	618	Well.
Aztec, San Juan	6,500	Farming, petroleum		282		898	Wells.
Farmington, San Juan	22,000	do		305		722	River.
Carrizozo, Lincoln	2,700	Ranching, railroad		[4] [illegible]		[4] 1,380	Well.[5]
Alamogordo, Otero	19,771	Defense installations, ranching	424	495		[6] 1,968	La Luz Spring.[6]
Tularosa, Otero	4,000	Farming, ranching, defense facilities		797		1,588	River.[5]
Do	4,000	do		[4] 1,251	[4] Mg. 142	[4] 2,566	Well.[4]
Truth or Consequences, Sierra	5,500	Ranching, health resort	255			826	Wells.
Vaughn, Guadalupe	1,400	Ranching, railroad			[4] F 1-2.54	[4] 532	Do.
Santa Rosa, Guadalupe	3,500	Ranching, tourist		616		1,062	River.[5]
Do	3,500	do		615		1,171	Well.[5]
Roswell, Chaves	35,000	Farming, ranching, petroleum		454		1,082	Wells.
Hagerman, Chaves	1,500	Farming		550		1,200	Do.
Artesia, Eddy	17,000	Farming, petroleum		501		1,022	Do.
Carlsbad, Eddy	28,000	Farming, potash	[7] 260	[7] 750		[7] 1,850	Do.
Jal, Lea	5,010	Ranching, petroleum			[4] F 1-1.6	[4] 602	Well.
Hurley, Grant	2,300	Copper			F 1-1.82	500	Wells.
Fort Sumner, DeBaca	2,300	Farming, ranching		255	F 1-1.91	820	Do.

[1] Both electric power and natural gas are available at all of these communities except Carrizozo, Truth or Consequences, Vaughn, Santa Rosa, and Fort Sumner, where only electric power and liquified petroleum gas fuels are available.

[2] Unless otherwise noted, chemical concentrations are summarized from New Mexico Health Officer, vol. XIX, No. 1.

[3] Other objectionable concentrations.

[4] Recent NMDPH analysis.

[4] Recent New Mexico Department of Public Health analysis.

[5] Partial supply.

[6] The quality of water available to Alamogordo has recently been materially improved by blending with imported surface water. However, this imported supply and fresh ground water sources in Tularosa Basin upon which Alamogordo also relies are limited, and continued and increased consumption will create need for conversion of brackish waters which are available in great quantities. White Sands Proving Grounds and Holloman Air Force Base also overlie the abundant brackish water resources of the Tularosa Basin. If brackish water conversion can be economically accomplished these resources can make great contribution to the continuation and expansion of these vital defense establishments. Location of a demonstration plant at one of these defense establishments is favored by (1) possible contribution to defense effort, (2) availability of extensive Federal facilities, (3) existing Federal control of lands, and (4) ready availability of large quantities of ground water in 2,000 parts per million to 8,000 parts per million ranges.

[7] August 1957 sample—Analysis by city of Carlsbad.

TABLE 8.—*Summary of watershed protection and flood prevention program in New Mexico (Public Law 566, 83d Cong.)*

Application	Area of watershed (acres)	Field examination completed	Work plan		Construction			Estimated cost
			Authorized	Completed	Authorized	Underway	Completed	
Arkansas River Basin:								
Tramperos	149,742	X	X	X	X			$508,620
South Dry Cimarron	212,244	X						
Cieneguilla Creek	248,317							
Monia Creek	139,776							
Carrizozo Creek	133,000							
Upper Dry Cimarron	113,800	X	X					
North Dry Cimarron	238,000	X						
Corrumpa Creek	249,000							
Carrizo Creek	250,000							
Perico Creek	195,200							
Upper Mora River	121,882							
Saltpeter	14,150	X	X	X	X			193,568
Colorado River Basin:								
Baker Arroyo	23,000	X						
Bloomfield	9,200							
Upper Frisco	236,160	X						
Upper Gila Valley Arroyos	27,000	X	X					
Pecos River Basin:								
Upper Rio Penasco	126,400	X	X	X	X	X		358,737
Zuber Draw	123,400	X	X	X	X	X		523,688
Macho Draw	1,348,800							
South Berrendo	303,120							
North Spring River	21,189							
Middle Rio Penasco	241,690	X						
Lower Rio Penasco	189,310	X						
Pecos Arroyos	47,808	X	X	X	X			142,049
Hackberry Draw								
Cass Draw								
Avalon-Alacran								
Rio Grande Basin:								
Hatch Valley Arroyo	22,500	X	X	X	X		X	[1] 227,860
Dona Ana Arroyo	6,950	X	X	X	X		X	[1] 160,094
Rio Puerco	311,000							
Pojoaque	128,620	X	X					
Arroyo Grande	9,080	X						
Las Cruces Arroyo	10,635							X
Santa Cruz	146,000	X	X	X	X			522,223
Arroyo Seco	14,650							
Alvillar Arroyos	3,700	X						
Prop Canyon and tributaries	16,000	X	X	X	X			287,403
Turley-Dee man Arroyo	2,040							

[1] Construction cost.

TABLE 8.—*Summary of watershed protection and flood prevention program in New Mexico (Public Law 566, 83d Cong.)*—Continued

Application	Area of watershed (acres)	Field examination completed	Work plan		Construction			Estimated cost
			Authorized	Completed	Authorized	Underway	Completed	
Rio Grande—Continued								
Tortugas Arroyo	15,584	X	X	X				$342,641
Caballo Arroyos	3,700	X	X	X	X	X		326,434
Leasburg Arroyos	12,720							
Fillmore-Apache Arroyos	18,500	X						
Belen watershed	69,760							
San Mateo watershed	185,760							
Lemitar-Polvadera	30,980	X						
North Alameda Arroyo	9,330							
Brazito-Mesquite area	30,450							
Lauson-Breedlove Arroyo	6,935							
Anthony Arroyo	3,800							
Closed Basins:								
Upper Tularosa	269,340							
Lordsburg watershed	30,000							
Southern High Plains: Central Lea watershed	250,000							

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7. Initial development, water salvage, and salinity alleviation action programs, Pecos River Basin, Pecos River Commission, New Mexico and Texas, February 1955.

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EXHIBIT 1

Tentative projections of the population of New Mexico Counties[1] *(Bureau of Business Research, University of New Mexico)*

	1950 census	1959	1960	1965	1970	1980
Bernalillo	145,673	257,100	264,000	354,500	463,600	672,200
Catron	3,533	2,900	2,900	2,600	3,200	3,200
Chaves	40,605	61,500	63,000	77,200	91,900	126,800
Colfax	16,761	13,900	14,100	16,900	20,200	26,200
Curry	23,351	34,600	35,500	42,900	51,600	70,700
De Baca	3,464	2,600	2,600	2,600	3,200	4,100
Dona Ana	39,557	60,500	62,300	75,700	94,000	133,500
Eddy	40,640	46,500	47,700	54,200	64,200	81,500
Grant	21,649	16,500	16,800	18,700	20,700	24,800
Guadalupe	6,772	6,500	6,600	6,700	6,900	7,000
Harding	3,013	2,000	2,000	2,200	2,600	3,100
Hidalgo	5,095	5,800	5,900	6,400	6,800	8,300
Lea	30,717	51,600	52,900	68,100	85,100	125,000
Lincoln	7,409	8,300	8,400	9,000	9,500	10,300
Los Alamos	10,476	13,000	13,500	14,000	14,600	16,800
Luna	8,753	12,000	12,200	14,200	16,500	21,400
McKinley	27,451	44,000	45,100	56,400	70,600	105,800
Mora	8,720	6,200	6,300	6,700	7,400	9,800
Otero	14,909	49,700	50,900	73,300	100,400	142,500
Quay	13,971	12,500	12,700	13,800	14,000	16,600
Rio Arriba	24,997	24,900	25,600	41,500	55,700	80,700
Roosevelt	16,409	15,500	15,800	17,400	20,400	26,400
Sandoval	12,438	9,900	10,200	13,200	18,200	28,200
San Juan	18,292	61,200	62,700	95,600	133,900	227,500
San Miguel	26,512	23,500	24,000	26,400	31,700	44,400
Santa Fe	38,153	42,100	43,200	49,200	61,500	86,100
Sierra	7,186	6,200	6,200	6,000	6,100	6,600
Socorro	9,670	10,500	10,700	12,300	14,100	17,800
Taos	17,146	15,100	15,500	17,400	19,600	25,800
Torrance	8,012	6,000	6,100	7,100	8,600	11,900
Union	7,372	5,700	5,800	6,400	7,200	8,700
Valencia	22,481	35,300	38,600	48,600	59,100	83,900
State total	681,187	963,600	989,800	1,257,200	1,583,100	2,256,700

[1] The above projections of populations of New Mexico counties to the year 1980 were prepared by: (1) calculating the rates of natural increase (births less deaths) and of migration for each of the counties for the period 1950–59 (and in most cases for 1940–50); and (2) projecting each of these two elements separately for the 5-year periods 1960–65 and 1965–70 and for the 10 years 1970–80.

The rates used for making the projections were in most cases modified—quite substantially in the case of some counties—from the historical rates on the basis of our knowledge and expectations of the resources of the particular county. Thus these projections are not simply extrapolations of the growth (or decline) of the past 2 decades but are, instead, attempts to provide reasoned estimates of what populations might be anticipated on the basis of what we now know about each of the counties. The ratios used for projection both natural increase and migration for each period for each county are available upon request.

The above projections are preliminary and will later be subject to two major adjustments resulting from (1) the results of the 1960 census and (2) a detailed analysis of the employment opportunities that might be reasonably anticipated in the near future.

EXHIBIT 2

[Reprinted from "Prosperity During Recession," 1958 Annual Summary Issue of New Mexico Business, Bureau of Business Research, University of New Mexico, pages 4 and 5]

THE NATURE OF OUR GROWTH

In the United States, and particularly in the West, we take growth for granted and assume that it is a necessary condition of existence. We are also inclined to assume that rapid growth is good per se. But it is important to know the sources and causes of that growth and to seek an understanding of their significance concerning the general health of our economy.

In New Mexico the nature of our rapid postwar growth has resulted in the development of a pattern of economic activity which has been relatively insensitive to the forces which since the war have been most responsible for the national recessions; namely, wide fluctuations in the demands upon the capital goods industries. At the same time the growth and the structure which it has produced have been particularly favored by expanding Federal expenditures for the national security. These facts are apparent from an examination of table 2, showing the growth and changing distribution of New Mexico employment.

Since 1947 the number of workers in the State has increased 124,000, a rate of gain of 61 percent, more than double the Nation's 24-percent gain in number of workers. But of those groups which have shown above-average rates of growth only two—Government (including the military) and services—have contributed as much as 10 percent of the total gain in number of workers. In fact, when the increase in military personnel is included, Government contributed over 40 percent of the entire growth for the period. And, although State and local governments have accounted for about one-third of the increase in this group, the largest share by far has been provided by the combination of Federal civilian workers and military personnel. As a result these workers, most of whom are concerned directly or indirectly with national security, make up over one-sixth of the total employment in the State—the largest single group. Whatever happens to them has a large impact upon the State's economy.

TABLE 2.—*New Mexico's changing economy as reflected in average monthly employment* [1]

	1947		1957		1958		Change: 1947-58	
	Number of workers (add 000)	Percent of total	Number of workers (add 000)	Percent of total	Number of workers (add 000)	Percent of total	Number of workers (add 000)	Percent change
All industries	202.5	100.0	314.7	100.0	326.5	100.0	+124.0	+61.2
Agriculture	50.6	25.0	39.8	12.7	39.6	12.1	−11.0	−21.7
Mining	14.2	7.0	20.6	6.5	19.5	6.0	+5.3	+37.3
Manufacturing	10.3	5.1	16.2	5.1	17.2	5.3	+6.9	+67.0
Construction	12.0	5.9	21.4	6.8	23.8	7.3	+11.8	+98.3
Transportation and utilities	15.3	7.6	21.7	6.9	21.2	6.5	+5.9	+38.6
Trade	35.7	17.6	57.5	18.3	60.1	18.4	+24.4	+68.3
Finance	3.5	1.7	8.8	2.8	9.8	3.0	+6.3	+180.0
Services	25.7	12.7	46.6	14.8	47.9	14.7	+22.2	+86.4
Government	35.2	17.4	82.1	26.1	87.4	26.7	+52.2	+148.3
State and local	(16.2)	8.0	(31.8)	10.1	(33.9)	10.4	(+17.7)	+109.3
Federal	(10.0)	4.9	(26.3)	8.4	(27.6)	8.4	(+17.6)	+176.0
Military	(9.0)	4.5	(24.0)	7.6	(25.9)	7.9	(+16.9)	+187.8

[1] Total employment includes wage and salary workers, proprietors and self-employed, domestic workers, and military personnel.

Source: Bureau of Business Research based on reports and information from New Mexico Employment Security Commission and U.S. Bureau of Census.

LETTERS TO STATE ENGINEER IN RESPONSE TO REQUESTS FOR COMMENTS ON NEW MEXICO'S WATER-RESOURCES PROBLEMS

STATE OF NEW MEXICO,
DEPARTMENT OF FINANCE AND ADMINISTRATION,
Santa Fe, N. Mex., September 15, 1959.

Mr. J. C. YATES,
Chief, Technical Division,
Office of State Engineer,

DEAR MR. YATES: The following observations are in reply to your letter of August 14, inviting this office to submit views and comments bearing upon a statement to the Select Committee on Water Resources:

Adequate definition and solution of New Mexico's problems with respect to water is believed to be dependent on the initiation and continuous operation of a planning program of broad scope, in which water is treated as one of several major factors in the development of the State.

This program would require elucidation of comprehensive, statewide development objectives which take into account the physiographic, economic, and cultural characteristics of New Mexico and the extent to which national and global trends of economic and technical evolution may affect the development of the State.

Such an elucidation would require continuous collaboration between many responsible agencies of government and private organizations and the application of techniques of economic and social research, regional planning, and engineering analysis. It is the expectation of this office, in accordance with the directives contained in the act establishing it, to work toward the initiation and coordination of such a collaborative process.

The uplands watershed study, which we have recently discussed with your office, can serve as a small-scale, pilot project for the study of water development problems of other small regions. Also, study of optimum water development and utilization for the State as a whole can employ techniques similar to those needed in the pilot study.

I regret that this office is not in a position to offer a more precise statement on New Mexico's water plans and problems.

Very truly yours,

DONN E. HOPKINS,
Acting State Planning Officer.

THE UNIVERSITY OF NEW MEXICO,
Albuquerque, September 17, 1959.

Mr. STEVE REYNOLDS,
State Engineer Office
Santa Fe, N. Mex.

DEAR MR. REYNOLDS: On behalf of the University of New Mexico and in response to the request in your letter of August 14, 1959, I submit the following views, comments, and suggestions relative to the subject of New Mexico's water needs and problems for inclusion in a report to be transmitted to the Senate Select Committee on National Water Resources from the State of New Mexico.

The following brief comments and suggestions on the vital subject of water resources in New Mexico are those which are conceivably of concern and interest to educators and which are within this realm of professional function.

The only justification for development and conservation of water resources is to improve and stabilize the economic and social status of the people living within the area concerned, and of future inhabitants. Until several decades ago the number of people dependent upon New Mexico's limited water resources was relatively small and the pattern of water use was relatively simple and uniform—primarily for agricultural and domestic purposes. This is no longer true. Population of the State has increased along with the variety and extent of demands upon available water supplies. Governmental activities of many types, industry, and recreation are typical of the activities which are of relatively recent significance in increased demands for water.

Adjustment of the broad pattern of water use through educational, economic, and social processes (coupled with appropriate technical achievements) may conceivably be the only effective means to a permanent solution of water problems in New Mexico, as well as in many other areas.

The more technical aspects of planning for and development of water resources, such as taking of inventories, projections based upon current and anticipated trends in water supply and demands, and predictions and solutions of related technical problems, should be the function of technically qualified agencies and individuals. It is, however, the responsibility of universities and other institutions charged with education, research, and guidance in economic and social aspects of human population growth and movement to insure that planning for future use of water resources includes constant consideration of the human problems as well as the technical problems involved.

Educational institutions, by reason of their special responsibilities and qualifications, can contribute to the development, use, and conservation of water resources in several ways:

1. Development through educational processes of a sound public understanding of the factors involved in water problems and the wise use of water resources.
2. Participation in a program to regularly and frequently evaluate the economic and social impact of current or proposed patterns of water development and use. It is suggested that such evaluation, if it is to be reliable and usable, must first be periodic, authoritative, and impartial.
3. Development of reliable standards or formulas with reference to the true economic value of water within various patterns of use. For example, in New Mexico it is particularly important that we arrive at some means by which the value of water when used for recreation, wildlife, and industry may be compared with the productivity of water used for purposes which are traditional but which may not have demonstrable legitimate foundation for priority of water use under present economic patterns and those patterns possible in the future.

Preliminary studies of the nature suggested have already been undertaken by a committee under the chairmanship of Dr. Nathanial Wollman, Economics Department, University of New Mexico.

In summary, I wish to express my conviction that because of the rapid growth in population and the possibility of further significant changes in the pattern of land and water use in New Mexico, we must proceed with caution and full cognizance of the complexity of the economic and social factors involved as we plan for water development and use. We are confronted almost daily with new and significant factors which must be considered.

On behalf of the University of New Mexico I offer the use of personal and physical facilities available here toward the achievement of a pattern of water development and use which will provide the most permanent economic and social benefit to the people of New Mexico and to their successors.

Sincerely,

TOM L. POPEJOY, *President.*

STATE OF NEW MEXICO,
DEPARTMENT OF GAME AND FISH,
Santa Fe, September 8, 1959.

Mr. S. E. REYNOLDS,
State Engineer, Santa Fe, N. Mex.

DEAR MR. REYNOLDS: Reference is made to Mr. J. C. Yates' letter of August 14 concerning Governor Burroughs' request that a statement be prepared by you for submittal to the Select Committee on Water Resources on New Mexico's water plans and problems in 1980.

Several months ago, we developed a list of the fishing improvements and developments that we would like to see carried out over a longtime period. We are enclosing a sheet showing these improvements without any attempt to show dollar value because the cost of construction changes so rapidly and we have no way of knowing in which year we might be able to undertake any specific development. We have thought of this in terms of perhaps a $4 million program spread out over a large number of years.

You may have this information, and if it does not satisfy your need, please advise us and we will help you with this matter further.

Very truly yours,

Fred A. Thompson, *Director.*

Water Resource Developments for Fisheries Management

New trout production facilities not fully investigated

Rio Grande Gorge: New rearing station; 15 to 20 cubic feet per second of water. Five miles of road, water development, raceways, feed and equipment storage, two or more residences.

Rio Grande Drainage Canal Rearing Station: 10 second-feet of water, raceways, etc.

Impoundments, small

High mountain lake improvement which would repair existing lakes, raise dams to prevent winterkill and create lakes of less than 10 acre-feet capacity.

Create about 100 surface acres of water, 25 sites.

In addition to this type of impoundment there are several small trout lake sites from 6 to 20 surface acres. Some of the feasible sites, except for the acquiring of water rights are—

Trout Creek, 15 acres near Luna.
Placer Creek Dam above Hopewell, 7 acres.
Hubbell Canyon (Cloudcroft), three sites from 3½ to 6½ acres.
Sawmill Creek (Red River), 20 acres.

Large impoundments or fishing areas that could be developed

Largo Canyon (south of Quemado).
Black Lake.
Via Grande.

Lakes that might be acquired if water rights and land could be purchased

Willow Lake (Eddy County).
Britt Lakes (small lakes near Roswell).
Murphy Lake (50 acres in Mora County).
Laguna Linda (Mora County), 14 acres.
Abbott Lakes, 50 acres.

Water rights to insure conservation pool

Bluewater Lake: another 20-foot depth or the total capacity of the lake.
Alamogordo Lake: 10,000 acre-feet.
El Vado Lake: 5,000 feet.
Cohiti Dam: 50,000 feet.

New Mexico State Park Commission,
Santa Fe, September 15, 1959.

S. E. Reynolds,
State Engineer, Santa Fe, N. Mex.

Dear Mr. Reynolds: The State Park Commission of New Mexico is extremely interested in the matter of maintaining and conserving water resources for recreational purposes, as well as for normal consumption and use in our growing State park system.

Thus we are happy to respond to your inquiry in connection with the nationwide study authorized by Senate Resolution 48 of the 86th Congress, 1st session.

In this vast arid area, fishing and boating water understandably comprises the prime attraction at three of our existing State parks. These three lake parks—Bluewater, Conchas, and Storrie—not only afford wholesome, healthful recreation for New Mexico families, they also are attracting additional thousands of vacationists from other States to New Mexico each year.

In addition to the three lake parks within our system at present, this commission has been authorized by the legislature to create a new park at Alamogordo Lake, which action will be taken as soon as arrangements can be completed.

Also, we have been informed that this commission will be delegated to administer two large recreation areas on the shores of the water to be impounded by Navajo Dam, after the current construction of that large dam is completed.

And, through the National Park Service, we have been approached twice thus far this year (1959) regarding the possibility of our assuming responsibility of administering recreation at Elephant Butte and Caballo Lakes, facilities of the Bureau of Reclamation.

(This commission is further tied into aquatic recreation matters to this State, being designated as the agency to enforce the New Mexico Boat Act of 1959.)

We are also greatly concerned with the matter of plentiful water supplies for human consumption and other normal usage at all of our seven existing State parks and others yet to be added to our system.

We now obtain such water in various ways—hauling it 17 miles into one park, utilizing a windmill over a well at another, buying piped water from a municipality in one instance, and pumping from lakes at two of the parks. Obviously, potable water is an ever-present concern for us.

Serving the fishing and boating public as indicated above, we cannot stress too vigorously the desirability of establishing adequate minimum pools behind all conservation or irrigation dams constructed in the future in New Mexico—where our average annual rainfall is but a meager 14 inches per annum.

The maintaining of such minimum pools is of vital importance here, not only for recreational use but also for the sake of the additional millions of dollars which visitors will spend in our State by reason of the existence of such pools for fishing, boating, and water skiing. With the travel-and-vacation business ranking as one of our top industries in New Mexico, and with our resident population expanding very rapidly, our economy will continue to need every additional tourist dollar we can attract to this wonderful State.

So the development and conservation of water resources for recreational use comprise a factor of paramount importance in New Mexico, from our viewpoint. Any allocation of public funds for such purpose must surely be considered sound investment, rather than expenditure.

Sincerely,

Joe M. Clark, *Superintendent.*

NEW MEXICO
HIGHLANDS UNIVERSITY,
INSTITUTE OF SCIENTIFIC RESEARCH,
Las Vegas, September 19, 1959.

Mr. J. C. YATES,
State Engineer Office,
Santa Fe, N. Mex.

DEAR MR. YATES: I have just returned from South America and have your letter of August 14 addressed to Dr. Donnelly. I hope the following information is not too late to be of value to you.

As you know, New Mexico Highlands University is currently engaged in a research program under the sponsorship of the Office of Saline Water. This program is developed to the point where a number of interesting conversion techniques have been considered and evaluated. One of these, in our opinion, is ready for a pilot plant investigation. We should, therefore, like to go on record as recommending that (1) facilities for pilot plant investigations of saline water conversion processes employing solar energy be allocated to the State of New Mexico and (2) that the southwestern demonstration plant, as set up under the Public Law 85-883, be located in New Mexico and operated under the joint direction of New Mexico Highlands University, University of New Mexico, and the New Mexico Institute of Mining and Technology, as per my letter to Dr. Miller dated May 8.

Yours very truly,

E. GERALD MEYER, *Director.*

NEW MEXICO STATE UNIVERSITY OF
AGRICULTURE, ENGINEERING, AND SCIENCE,
OFFICE OF THE PRESIDENT,
University Park, N. Mex., September 15, 1959.

Mr. S. E. REYNOLDS,
State Engineer,
Santa Fe, N. Mex.

DEAR MR. REYNOLDS: In accordance with the request received from Mr. J. C. Yates, a report on the "Problems Associated With Water for Agricultural Production" is enclosed. We are sorry that this report missed your deadline by 1 or 2 days.

The New Mexico State University Committee which considered your request, together with the information from Senator Kerr, has listed a number of problems which are important to consider in connection with water for agricultural production. We have not attempted to go into detail on these because we understand from a telephone conversation from Mr. Yates that your report will be limited to approximately 10 pages, plus any supporting material which you may wish to include.

We hope that this information will be of assistance to you in preparing your report to the Senate committee.

Sincerely yours,

R. B. CORBETT, *President.*

REPORT TO S. E. REYNOLDS, STATE ENGINEER, IN ANSWER TO REQUEST FOR INFORMATION ON PROBLEMS ASSOCIATED WITH WATER FOR AGRICULTURAL PRODUCTION

A committee composed of several members or the New Mexico State University, College of Agriculture, College of Engineering, Agricultural Experiment Station, a member of the ARS staff, and two representatives of the New Mexico State Farm Bureau reviewed the request of the State engineer for information on the above subject. The following is a brief statement on each of the items which were considered important problems associated with water for agricultural production. These items are included under three headings: (1) General water problems and those associated with (2) surface water and (3) ground water.

I. GENERAL WATER PROBLEMS

(a) Irrigated land

The total land area and inventory acres by types of land use, New Mexico, 1954 and 1975 projected, was discussed with the State engineer, Soil Conservation Service, and others in the spring of 1958. The following figures came from these discussions.

Total land area and inventory acres by type of land use, New Mexico, 1954 and 1975 projected

[In thousands of acres]

	Total land area		Inventory acres	
	1954	1975	1954	1975
Cropland:				
Dry	1,572	1,542	1,572	1,542
Irrigated	873	973	873	973
Total	2,445	[1] 2,515	2,445	[1] 2,515
Range	[2] 50,194	[3] 49,412	[2] 35,609	[3] 34,827
Forest and woodland	21,329	21,329	11,558	11,558
Other land	3,799	[4] 4,511	655	655
Total	77,767	77,767	50,267	49,555

[1] Increase due to conversion of 70,000 acres of range to irrigated land.
[2] Includes 16,000 acres wild hay.
[3] Decrease due to conversion of 70,000 acres to irrigated land and 712,000 acquisition by defense agencies, urbanization, and highways.
[4] Increase due to conversion of 712,000 acres rangeland to urbanization, highways, and defense use.

It is assumed by the New Mexico State University Committee that the projections of an increase of about 100,000 acres of irrigated land by 1975 would hold for 1980.

(b) Population increase

It is estimated that the population of New Mexico may increase from the estimated 890,000 in 1957 to 1,390,000, or 500,000 increase, by 1975 to 1980. The U.S. population may increase from about 175 million to 250 million by 1980. This increase in population will result in widespread municipal and industrial expansion on to agricultural land.

(c) *Municipal and industrial expansion on to agricultural land*

Municipal and industrial expansion has taken a considerable amount of land out of agricultural production in New Mexico. For example, in Bernalillo County commercial farms have been reduced from about 500 farms 25 years ago to an estimate of 25 farms now. These farms were broken up by subdivisions. The remaining farms are expected to disappear within the next few years. This type of development is eliminating developed irrigated farms while at the same time we are proposing to develop new irrigated farms in New Mexico at a very high cost per acre. Some planning of municipal and industrial development might hold these losses of agricultural lands to a minimum.

(d) *Water laws*

Water laws as they apply to agricultural lands in New Mexico have been challenged in two directions in recent years as follows:

Pueblo rights.—The case of the city of Las Vegas, N. Mex., claiming unlimited rights to the water of the area due to the record that the town of Las Vegas was established by the Mexican Government as a Mexican pueblo on April 6, 1835, and that this establishment was recognized by the Treaty of Guadalupe Hidalgo in 1848. If this case should be upheld in the courts and extended to other areas this could have a very detrimental effect on a number of irrigated areas in New Mexico.

Federal claims to water originating on Federal lands.—If this contention should be accepted by the courts, it could result in a weakening, if not the elimination, of numerous State water rights and would very greatly reduce the stability of the irrigated agriculture of New Mexico and of other Western States.

Since water rights were recognized in the New Mexico State constitution and in many court cases since that time, It seems that the agricultural development based on these water rights should be protected in order to protect the large investments in irrigated agriculture held by several thousand persons in New Mexico and other Western States.

(e) *Beneficial use*

Water law in New Mexico is based on two principles: (1) Prior appropriation and (2) beneficial use. The concept of beneficial use is not very clearly defined or closely administered. As the competition for water increases due to additional demands from increased population, municipal and industrial uses, and recreational uses, it seems evident that more consideration must be given to the proposition of getting full value from the water which is used for various purposes. Some of the most wasteful uses—for example, irrigating poor, unproductive land, and using water for evaporative air conditioners, and pumping an excessive amount of ground water—may be questioned and conceivably eliminated. In any changes, due consideration must be given to the water right conditions in each case.

(f) *Water for recreational uses*

The increase in population in New Mexico coupled with a high average per capita income and an increasing amount of leisure time due to a continually reduced work week, has increased the demand for water for recreation. These recreational uses include fishing, camping, boating, and water skiing. Recreational uses of the reservoirs built primarily for irrigation and power have increased to the point where it is difficult for those in charge to use the water—make required diversions even—to the extent of draining the reservoirs to supply the originally intended uses. This is a problem facing both the recreation people and the agricultural users. The questions of the water rights and beneficial use of water are being raised in connection with this problem.

II. SURFACE WATER

(a) *Prevention of evaporation and seepage losses*

An estimated annual average of 150,000 acre-feet of water is lost by evaporation from Elephant Butte Reservoir. Many additional thousands of acre-feet are lost by evaporation from streambeds, irrigation ditches, and from devegetated rangelands.

Seepage losses in canals and ditches conveying irrigation water from the streams on reservoirs to the fields often run 25 percent or more of the available water. When it costs from $4 to $8 to pump water, it is a distinct economic loss to not deliver that water to the crops. Also, some of the ground-water reserve may be permanently lost with no economic benefit resulting. Some maintain that seepage water really is not lost, but it obviously is lost to those who have made an investment in an attempt to secure its use, and it may be lost to the community or State by evaporation or by changing the location of the water so it is not available to other users.

Much information is needed on the methods in use in reducing these losses. Considering the cost of these losses, it seems evident that more resources could well be put into research and other efforts to reduce them to a minimum.

(b) *Control of phreatophytes*

Unusable water-loving plants account for huge losses of surface water. If these plants, such as saltcedar, willows, and cottonwoods, could be controlled along stream courses, large amounts of water could be saved. The alternative to controlling these plants is to keep the water away from their roots by lined ditches and special channel developments.

(c) *Stream channel improvement*

Stream channel improvement would be done to eliminate and control water-consuming vegetation, provide a more direct route of the river and tributaries by channelization, and place levees to control the riverflow. Some of this work, which has been completed, has resulted in large savings of water. Additional work is required.

(*d*) *Watershed management*

Watershed management offers an opportunity to reduce evaporation, reduce silting of reservoirs, and produce more ground-water storage, which could result in benefits both to the stockman and the irrigator. Much information is needed on methods of management and the results in terms of water yield from various management practices.

(*e*) *Relationships between crop production and water requirements as influenced by soil management practices*

The soil management practices may have a considerable effect on the amount of water required to produce a crop and on the resultant yield of the crops from certain soils. If the measure of high production per unit of water used should be applied, then much more emphasis would be required on soil management practices. Additional research and extension work is required to make progress in this area.

III. GROUND WATER

(*a*) *Brackish water conversion*

The State of New Mexico has large amounts of brackish ground water. Several communities supplied the Department of the Interior, Division of Saline Water, with information on their brackish water supplies and need for converting this water to potable or near potable quality. If some means could be developed to convert our saline water to usable quality at a reasonable cost, the economic potential of New Mexico would be greatly increased. It is hoped that the brackish water conversion plants planned for the Southwest will be located in a New Mexico community. This would be one important step in the solution of the State's industrial and municipal water needs and possibly relieve the competition for water now used for irrigation.

(*b*) *Ground water recharge*

Ground water is being used at a much faster rate than it is being replaced. Some efforts have been made to increase the recharge rate. One of these efforts was started by Lea County under the direction of Mr. E. G. Minton.

An increase in the recharge of our ground-water basins could do much to delay the time when the amount of water will be so reduced that the present uses of water in these areas must be curtailed.

IV. OTHER ITEMS MENTIONED BY THE COMMITTEE

Other items mentioned by the committee will be listed by title only:

(*a*) Weather control.

(*b*) Type of organizations which may be needed to get the most beneficial use of water.

(*c*) Increased efficiency of the use of both surface and ground water for all purposes.

(*d*) Improved pump efficiency.

(*e*) Improved power for pumping and source of energy for converting brackish water, possibly atomic energy.

(*f*) Better conservation methods in the use of water for all purposes, including agriculture.

New Mexico Association
of Soil Conservation Districts,
August 29, 1959.

Mr. J. C. Yates,
Chief, Technical Division,
State Engineer Office, Sante Fe, N.Mex.

Dear Mr. Yates: I certainly appreciate the opportunity to contribute my views on New Mexico water resources, plans and problems to you for consideration in your report to the Senate Select Committee on National Water Resources. The program of this committee, as outlined in the material that you sent me, will fulfill one of our greatest needs pertaining to the Nation's water problems—that of collecting available research data on water resources at one location and analyzing this information preparatory to the formulation of a national water resources policy.

I note in reviewing this material that the programs of Federal agencies will be reviewed as well as the opinions of private parties and private groups. For this reason, my comments will pertain more to problems of water use that have been called to my attention during my tenure as president of the New Mexico Association of Soil Conservation Districts and as a member of the New Mexico Soil Conservation Committee. There is no need for me to review the programs of our Federal agencies except in terms of problems which have come to my attention. If we can find solutions to these problems, we will pave the way for these agencies to make even greater contributions.

We are all concerned with a fair and equitable distribution of water resources among all sectors of the State's economy and among all users of the State's water resources. A maximum degree of coordination and planning for water use will be necessary to assure the most efficient use of the State's water resources. The solution of the problem of achieving proper balance among the users of the State's water will require teamwork among those in professional and scientific fields who contribute to our knowledge concerning the nature, occurrence, control, and utilization of water. Another factor essential to efficient water use is coordination among the many agencies who plan, construct, and operate water development projects. The achievement of coordinated teamwork requires interchange of information and mutual understanding among the various organizations concerned in New Mexico water resource problems. It is hoped that this coordination and understanding can be attained by the study that you are making and by the opportunity for all of us to contribute to the State's report to the Senate Select Committee on the Nation's Water Resources.

Recently, the interest of the soil conservation districts of New Mexico has been focused upon watersheds as a logical unit for contributing to water control and proper water use in the State. As you are aware, we are actively supporting the Watershed Protection and Flood Prevention Act, (Public Law 566, 83d Cong.). We have found a problem in applying this law to New Mexico conditions. One objective of the various laws for flood control and watershed protection is to permit work of this nature to begin on the upper reaches of the watershed. The floods are then controlled closer to the point of their origin. Existing laws afford the opportunity to create intersupporting projects. Public Law 566 is designed for flood prevention on the upper reaches of the streams. In New Mexico these occur at the higher elevations. The value of any farmland at these higher elevations is limited in that the range of crops that can be grown is small and by the short growing season. The general pattern of irrigated cropping in one of our valleys begins with flood irrigated native grass at the higher elevation and, through stages, reaches intensively farmed cotton-farm land at lower elevations. Although the value of these intensively farmed areas is enhanced by the work on the upper watershed, the number of watersheds that have potential for construction under this law is limited by the lower value of the farmland at higher elevations. The limited number of potential watershed projects is a factor of the size limitation of watersheds as well as to the means of computing damages. Thus, I would suggest a reevaluation of the justification for watershed protection and flood prevention work in New Mexico, with the possibility of creating a wider range of participation. The benefits of an expanded program would be far reaching.

I would like to suggest that the possibility of providing a more uniform water supply to the old irrigated areas among the foothills along the east slope of the mountains be thoroughly investigated. These irrigated areas have been marginal since their inception, although they have had periods of adequate water and good crop production. New Mexico has a relatively small amount of unappropriated water. I believe the possibility of diverting San Juan and/or Rio Grande water to these regions should be thoroughly explored. I believe that we should concentrate on increasing productivity on already existing irrigated farmland prior to development of more irrigated land.

The pattern of rainfall in New Mexico results in many flash floods and rapid runoff. A large percentage of this water ends its journey in our many "playa" lakes. A small percentage of this water reaches our underground basins. It is my opinion that we should conduct more research on the possibilities of recharging the floodwater into the underground basins at relatively high elevations. This will permit New Mexico farmers maximum benefit from underground recharge. These projects should be accomplished with minimum conflict of existing water rights.

Many of our rural areas would benefit greatly from more uniform water supplies for both agriculture and industry. Many of our people must turn to industry for a livelihood. Structures which will regulate our State's waters and create more uniform flows will be of great benefit in the development of our rural areas, as well as provide more adequate water supplies for the municipalities of the State.

Other programs of interest to the soil conservation districts of New Mexico, and that we feel merit study, are:

Desalinization of ocean water. If desalinization can be accomplished at a low cost, more of this water could be used to fulfill the needs of the coastal States. This would permit a higher percent of the water originating from this State to be used by the citizens of this State.

Saline underground water. The possibility of using saline underground water in New Mexico should be investigated. Perhaps processes for desalinization may be developed which will permit this water to be used for industrial purposes as well as for irrigation and by municipalities.

Phreatophyte control. We encourage continued studies on the control of phreatophytes. Many of our streams are still lined with salt cedar, cottonwood, willows, and other plants which use much of our State's waters.

Climate control. Continued study on climate control is encouraged.

Atomic power applicability. The possibility of using atomic power on water resource problems should be encouraged. Cheaper atomic power sources could be used in pumping water and in desalinization processes.

Our soil conservation districts have emphasized efficient water distribution and use from main canals to irrigated fields. We will continue to emphasize this essential conservation measure.

I realize that many organizations have already contributed to the solutions of the problems outlined above. A continuation of the very fine efforts of all organizations concerned will do much to stabilize the future of New Mexico agriculture. A coordination of efforts and a clearly defined responsibility for each will assure this continuation. Any national water policy should be flexible and adjusted periodically to the changing needs of the Nation. Any national water policy should be adjustable to the needs and character of any geographic area or specific conditions in an individual State.

Thank you again for the opportunity of contributing to New Mexico's report to the Senate Select Committee on National Water Resources.

Sincerely yours,

J. Lewis Merritt,
President.

New Mexico Institute of
Mining & Technology,
Research and Development Division,
Socorro, N. Mex., September 14, 1959.

Mr. S. E. Reynolds,
State Engineer, Santa Fe, N. Mex.

References: (*a*) Your letter of August 14, 1959; (*b*) letter to Senator Robert Kerr from Gov. John Burroughs, July 6, 1959; (*c*) letter to Gov. John Burroughs, from Senator Robert Kerr, June 23, 1959; (*d*) Senate Resolution 48 (Rept. No. 190).

References (*a*) through (*d*) relate to certain plans for implementing further study of water resources and contain requests for views and comments by the NMIMT on the subject of water resources and New Mexico water plans and problems to 1980.

The reference information does not indicate a direct connection with the authorized activities at the NMIMT, since our approach to the problem is physical rather than economical or political.

Although we recognize that population growth figures frequently quoted and expected by many will result inevitably in a decreased standard of living with respect to water requirements, our limited interest in the physical aspects of the problem has been maintained. Indeed, we take the position that the social aspects of the problem cannot be approached reliably without a much increased knowledge of all phases of ground and surface hydrology, climatology, and reservoir technology. Education and research become, therefore, our most urgent needs as we see them and we urge greater attention to these fundamentals. Basic facts are necessary if our organized society is to avoid "emergency management" of water resources.

New Mexico's position appears to be extremely critical. We have been faced with a population growth, but more important is the fact that increments of population which we have added require large quantities of water for the maintenance of their standards of living through recreation. Looking at the country as a whole we see enormous developments in the recreational use of water; but we have done little or nothing in spite of the fact that the economic advantages have been fully established.

We need to establish and support institutes for the study of the physical aspects of the water resources problem. We need to analyze and to some extent plan for our population growth, at least that portion of our growth which we presume to influence through our chamber of commerce and other promotional activities. We need to establish many social and economic studies on the problem. We need, above all, to inform our citizens and political leaders concerning the basic facts of the problem. We need to establish, on a national scale, a council to examine the organization of the Federal Government with respect to the water resources problem and perhaps facilitate the immediate dissolution of the monopolistic and proprietary management of the water resources problems by the Department of the Interior and its subordinate agencies.

Sincerely,

E. J. WORKMAN.

NEW YORK

STATE OF NEW YORK,
DEPARTMENT OF AGRICULTURE AND MARKETS,
Albany, September 15, 1959.

Hon. ROBERT S. KERR,
U.S. Senate, Washington, D.C.

DEAR MR. SENATOR: At the request of Governor Rockefeller, I am enclosing a statement on the water problem in New York State. I hope this material will be useful to you.

Very truly yours,

DON J. WICKHAM, *Commissioner.*

WATER NEEDS REPORT FOR NEW YORK STATE

New York has many water problems. This is not a new situation. The problems are expected to increase in the future.

I. BACKGROUND

1. Historically, the planning and building of a canal system for transportation involved a great deal of study and firmly established the State's right to certain inland waters. Later, beginning about World War I, the State water power and control commission was created. Its role centered around the allocation of excess water to municipalities, power companies and industrial enterprises. In more recent years, the State has become involved in numerous activities, including investigation, pollution control, flood control, drainage improvement districts and water districts. These programs were generally assigned to existing departments and agencies and were many times carried out as independent activities with only limited correlation between agencies or departments.

With a complex of water activities being created and new problems such as irrigation coming into the picture, the State soil conservation committee and the State association of soil conservation directors in 1952 undertook a study of the whole water problem. This group initiated a study of legal background as to the legislative and legal history of water rights in New York. They collected similar information from other States. This group, lacking facilities to adequately carry forward a prolonged study, was able to interest the committee on natural resources in the worthiness of this work. This legislative committee picked up the study, completed it and has made continued basic water studies to date. The annual reports of this committee have brought to legislative and public attention the need for an overall approach to solving our present and future water problems.

The temporary State commission on irrigation created in 1955 has also been active in the study and data collection of water use and needs. This committee, while primarily interested in irrigation, has worked closely with the joint legislative committee on natural resources and has made many worthy contributions toward better understanding of our water problems.

2. Use of water in New York: Water is a basic necessity to man. Practically everything used or undertaken by him requires the use or availability of water. Some major uses and users are given below:

(*a*) Municipal water: Cities and urban areas need water not only for human consumption, but also for fire protection, sewage disposal, street cleaning, air conditioning, heating and many other uses. The per capita use of water has steadily increased due to wide public acceptance and demand for such things as air conditioning and improved sanitation facilities. The problem of fulfilling these water demands has forced most of the larger cities to seek means of augmenting their presently developed water facilities. It is estimated that domestic water consumption, supplied by municipalities, will total near 3¼ billion gallons per day by 1980.

(*b*) Associated with municipal requirements is industries' need for water. Industrial processes and activities require vast amounts of water. Except for power, the bulk of our industries is located in or near municipalities. With the recognized need of a continued healthy and expanded industry for the State, this water requirement is most important. No estimate of the present needs or future requirements of industry could be ascertained for this report.

(*c*) Our canal system requires great quantities of water for its operation. From 50 to 60 million gallons per day are required for this purpose. Proposals for enlargement of the canals would entail development and use of additional water.

(*d*) The use of water for recreation purposes has increased rapidly in past years and is expected to continue into the forseeable future. This use requires the presence of predictable bodies and flows of water at all times. Vast quantities of water will be needed to fulfill these needs.

(*e*) Agriculture's need and interest in water are vital to the State. With predicted sharp increases in population and a continual reduction in production acreage, the necessity of heavier agricultural production must follow. Rapid technological advances have taken place in agriculture in recent years but the control of water remains a main limiting factor to maximum crop output. Agriculture's water problem involves not only supplemental irrigation but the avoidance of excess water, through drainage and flood prevention. It is estimated that approximately 750,000 acres are irrigated at present in the State. This activity is expected to increase at least fivefold by 1980. In terms of water needed by 1980, irrigation alone will require the availability of at least three quarters of a billion gallons of water per day during the growing period.

II. AGRICULTURE'S WATER PROBLEMS

This report recognizes the right and need of water by other users. The lack of extensive information on the water problems of nonagricultural users limits further treatment of the needs of these users in this report.

1. Excess water problems

(*a*) *Flood prevention.*—A high percentage of our best agricultural land is located in valleys and a part of this land normally is subject to flood damages. Where subject to flood, the hazards of cropping or making the best use of this land is limited.

In 1955, as a result of Federal legislation (Public Law 566), farm interests began studies aimed at implementing State legislation to take advantage of the Federal law. The result was the passage of the New York State County Small Watershed Protection District Act, administered by the department of agriculture and markets. Though aimed primarily at flood prevention, both the State and Federal legislation provide for multipurpose development of the water resources of a watershed.

This program is progressing satisfactorily. It appears that this program will provide the means of attacking the problems, both rural and urban, in upstream areas where flooding is acute. A recent inventory conducted by the USDA, Soil Conservation Service, indicates that a total of 55 to 60 watersheds appear feasible under this program.

(*b*) *Drainage.*—Drainage has long been recognized as a serious agricultural problem. A number of activities and programs exist in the State to assist landowners with drainage problems.

On individual farms, the problem seems well covered by existing Federal, State, and locally sponsored programs. The county soil conservation district, working with State and Federal agencies, provides technical assistance. The Federal ACP program provides for financial assistance in this work.

In larger drainage projects, requiring group action, there is provision under the county drainage improvement law for organizing quasi-governmental local districts to do such improvements. This activity is administered by the State water power and control commission. This program has worked well in the few areas where it has been used in the State.

Under the County Small Watershed Protection District Act there is provision for doing needed drainage work.

The problem of drainage appears to be reasonably well covered in New York State, by present programs.

2. Agriculture's water needs

(*a*) *Domestic needs.*—The domestic water needs per capita of agriculture's people have increased similar to those in the cities. Modern home requirements have exceeded the developed supplies of old wells and springs. In most cases, these problems are being solved by the individual owners with little if any governmental type assistance. In some areas of the State, it appears that this problem may require some kind of group action, if adequate supplies are to be developed.

(*b*) *Fire protection.*—This is not a new problem but with improved rural firefighting equipment of recent years it has received more attention. Under the present county soil conservation district program, there is provision for construction of farm ponds. This problem appears to be reasonably well covered by present programs.

(*c*) *Stock water.*—The water requirement for this purpose seems adequately met by the farm pond and spring development activities provided through the county soil conservation district program.

(*d*) *Spray water.*—This need, likewise, seems to be reasonably well met through the farm pond.

(*e*) *Irrigation.*—One of the most limiting factors to increased or reasonably predictable farm crop production is water during critical periods of the crops' growth and maturity. Normal rainfall simply does not provide the right amount of water at the critical time of crop need. As a result, more and more commercial farmers are looking toward supplemental irrigation as a means of insurance and increased production of crops.

At present, the main areas doing supplemental irrigation are where natural and cheap water supplies are available. These sources of water are limited and, for the main part, being used pretty well up to the limit of present availability.

It appears that the need for irrigation will continue and is expected to increase at least five times by 1980. New supplies and sources of water will need to be developed if this increase is to be met.

At present, under the county soil conservation district program, landowners are assisted in building ponds that may be used for this purpose. The potential development of irrigation water under this program is limited by the lack of suitable sites and normally excessive costs associated with storage of water in relatively small reservoirs. This program cannot be expected to solve agriculture's irrigation water problem.

The county small watershed district program provides for development of irrigation water in multipurpose water retaining structures. It offers some possibilities for providing economical water storage in those relatively few watersheds where the Public Law 566 Federal program will apply. The lack of suitable reservoir sites is a major limitation, even in these watersheds.

In approaching the question of water needs for irrigation, the problem is twofold.

The first is a legal problem. Under existing riparian doctrines, only adjoining landowners to streams or bodies of water are legally entitled to use such water. This doctrine, as stands, prohibits the owners not bounding water from such potential sources of water. The doctrine, while permitting owners adjoining water to use such water, also makes them liable to other riparian owners if the natural quantity or quality of water is altered by their use of the water. Under these circumstances, the risk to a landowner using the quantities of water required for irrigation is considerable.

The second problem is one of storing water during periods of excess supply and use of this water for irrigation during periods of need. This will require expenditures of planning, construction and transportation of water beyond the financial means of an individual. It will require some type of group action with at least quasi-governmental status. It will probably involve either State or Federal financial assistance in the original cost of the planning and construction.

A great deal of study and investigation has taken place on this question by the State temporary commission on irrigation. There appears to be a great deal of more work to be done before widespread supplemental irrigation is possible.

(*f*) *Present agencies and programs in New York involved in agricultural water.*—

1. Soil Conservation Service, U.S. Department of Agriculture.

2. ACP program of the Agricultural Stabilization Committee, USDA.

3. Corps of Army Engineers, U.S. Department of Army.

4. Extension Service.
5. Division of lands and forest, New York State Conservation Department.
6. Division of fish and game, New York State Conservation Department.
7. New York State Department of Agriculture and Markets.
8. New York State Department of Health, Pollution Control Board.
9. New York State Flood Control Commission, New York State Department of Public Works.
10. The Water Power and Control Commission, New York State Conservation Department.
11. New York State Soil Conservation Committee.
12. Temporary State commission on irrigation.
13. Joint legislative committee on natural resources.
14. County drainage improvement districts.
15. County soil conservation districts.
16. County small watershed protection districts.
17. County water districts.

The above list, which may not be complete, illustrates the array of agencies or programs having an interest related to affecting the use and development of water on agricultural lands. One of our problems in considering agricultural water needs is the number of agencies with which one must deal.

III. THE 1959 ACT CONCERNING WATER RESOURCES AND DEVELOPMENT

The joint legislative committee on natural resources in 1958 undertook a State program geared to the study, planning, and development of the State's water resources.

The resulting act, passed into law in 1959, enlarged the duties of the water power and control commission to include comprehensive study and planning of the State's water resources on a multiple use basis.

This program is designed and expected to provide the means of finding solutions to many of our water resource problems. It represents a tremendous forward step in recognizing the State's responsibilities in the planning and development of water resources.

While the 1959 Water Resources Act represents a forward step in approaching overall water use, there remain a number of problems that appear to need further attention.

IV. FUTURE ACTIVITIES AND AREAS OF ATTENTION NEEDED

1. An inventory of present water needs and future requirements

A detailed study conducted on a watershed basis. It should include specific information on the present and anticipated water requirements by all users. A study of the water producing and water storage or control potentialities should be determined. This information is essential to future planning. It could well be one of the first acts of the enlarged water power and control commission.

2. Study of the numerous State, Federal, and local programs interested in water with a view toward combining and integrating these activities where possible

This could well be a legislative or administrative activity.

3. A basic research program

This type of information is needed for long-range planning and development work. A few subjects that could be considered are given below.

(1) Processes and practicability of salt water conversion.

(2) Manipulated rainfall. Practical application control.

(3) Economical means of pollution treatment in stream or water bodies.

(4) Financing—cost sharing information. Public benefits, values, etc.

4. Study of our canal and waterway system

In any consideration of New York water resources, it is difficult to avoid consideration of the canal system. At present, consideration is being given to the transfer of the barge canal to the Federal Government for development as an inland waterway. The canal controls nearly 40 percent of the State's watershed area. The question of who shall control the rights to any excess water in this area could be vital at some future date.

Another question is whether this natural aqueduct running through some of our heaviest populated areas might not be considered, at least in part, for purposes other than transportation. With other forms of transportation available, this waterway might be of greater public value if considered as a means of collecting and distributing water to agriculture, industry, and municipalities, rather than only as a means of transportation.

5. *Further study of water rights*

The solution of some of our present as well as future problems rests with finding legal ways to provide for our needs under our riparian rights doctrine.

Acknowledgments: The Soil Conservation Service, the Extension Service, and the State soil conservation committee all actively assisted in the preparation of this report. This assistance and cooperation are deeply appreciated.

NORTH CAROLINA

State of North Carolina,
Department of Water Resources,
Office of the Director,
Raleigh, N.C., September 23, 1959.

Hon. Robert S. Kerr,
U.S. Senator, Senate Office Building,
Washington, D.C.

Dear Senator Kerr: Please refer to letter of July 10 to you from Mr. Robert E. Giles, administrative assistant to Gov. Luther H. Hodges, in reply to your letter of June 23 to the Governor requesting a statement, in connection with Senate Resolution 48, 86th Congress, 1st session, as to the water problems of North Carolina, both present and anticipated to arise between now and 1980, and the views of the Governor, or the appropriate officials of the State, as to what should be done toward the solution of these problems.

The new board of water resources, indicated in Mr. Giles' letter and named in the heading of this letter, took their oaths of office on August 28 and will not have their next meeting until October 8. I feel sure that they will concur in the statements which are set forth below and which are presented at this time without reference to the board in order to fulfill your request that the material be made available to the Senate Select Committee on Water Resources not later than October 1. The material is generally arranged in accordance with attachment 1 to your letter.

Summary of water resources available.—The average annual precipitation in the United States is about 30 inches. The average annual precipitation in North Carolina is about 49 inches. Records of gaging stations in the State indicate that the average flow and the minimum flow in its streams is 29 billion gallons and 2 billion gallons per day, respectively. The people of North Carolina will have plenty of water in the future if they conserve it and use it wisely. They must, however, cease to harbor the illusion that water resources are inexhaustible.

Statement on withdrawal and use of water.—Unless the misuse of water wealth is checked and sound principles of conservation and proper use of water are adopted, more and more shortages of water will occur. The monetary loss to agriculture in North Carolina, caused by the 1954 drought, is estimated as $50 million. During 1953 and 1954, 26 counties and 39 counties, respectively, were declared drought emergency areas by the Federal Government. These situations indicate the ever-increasing need for conservation of the State's water resources. Action must be taken to store water in times of abundance in order to provide for requirements in time of scarcity. Public water supplies that were affected in 1953 and 1954 amounted to 14 percent of the towns in North Carolina. In the mountain region, 16 towns had water shortages of which 14 pertained to surface water supplies and two pertained to ground water supplies. Twenty-two piedmont towns had water shortages of which 17 pertained to surface water supplies and 5 pertained to ground water supplies. In the coastal plain region, six towns had water shortages of which four pertained to ground water supplies and two pertained to surface water supplies.

Fundamental problems.—Study of these drought areas and county and town public water supplies indicates the ever-increasing need for conservation of the State's water resources. Although the State has ample average rainfall and ample average flow in its streams, the supply is not evenly distributed by nature to give the maximum, or in many cases an average, economic balance for agriculture, industry, and public water supplies. More knowledge and planned conservation of the State's water supplies, both surface water and ground water, are prerequisite for continued prosperity, increasing development, and the general welfare of North Carolina.

Because of its geographic location, about one-fourth of the State of North Carolina is exposed to varying degrees of salt water intrusion of its surface and ground water sources. The degree of intrusion, and how far salt water extends above the mouths of the rivers, are questions that cannot be fully answered at the present time. Considerable data regarding such intrusion has been obtained through cooperative agreements between the U.S. Geological Survey and the North Carolina Department of Conservation and Development. Additional data will be needed as the municipal and industrial growth of the coastal region area increases and the need for adequate water supplies becomes more acute.

Ground water problems.—Most parts of the coastal region will yield large quantities of water from wells. Thousands of wells have been drilled in the piedmont region, and millions of gallons of ground water are used daily in this area. Because of the fact that surface water supplies have generally been readily available in the mountain region, not much information regarding ground water supplies and conditions in this section of the State is available.

A considerable part of the money spent for drilling, boring, and digging new wells in North Carolina is being wasted because of a lack of adequate information on ground water conditions. This situation has been improved because of a law, passed by the 1957 session of the general assembly, which required welldrillers to submit samples and information to the department of conservation and development. The water resources responsibilities of this department and of the division of water pollution control of the State board of health were transferred to the department of water resources created by the 1959 session of the general assembly, effective September 1, 1959. Many of the State's ground water problems are concerned with providing information which will make possible the use of ground water. There is a need for greater knowledge of the changes in ground water supplies, the effects of greater concentration of pumping, the seasonal effect on water levels, and the rates of replenishment of ground water supplies.

Water use for pollution abatement.—The 1951 session of the general assembly created within the State board of health a permanent committee to be known as the State stream sanitation committee, which shall be composed of six members (presently seven members) having had experience in the field of agriculture or in the wildlife activities of the State or in waste disposal problems of municipal government or in the field of industrial waste. The duties of the committee are to develop and adopt classifications of State waters, survey all waters and identify those which ought to be classified, assign a classification to each identified water, and hold public hearings regarding assigned classifications. The committee is empowered, in connection with assigned classifications, to issue permits to make new outlets, construct or operate new disposal systems, alter or change the construction or method of operation of existing disposal systems, or increase the quantity or change the nature of wastes discharged. The committee may issue special orders directing any person responsible for pollution to take action to alleviate or eliminate pollution.

No person shall discharge waste in violation of a special order. No special order shall be issued except after hearing unless the person affected thereby consents. The person against whom a special order is issued shall have the right to appeal. The committee shall encourage voluntary action and shall have the power to issue certificates of approval of proposed plans for voluntary action and to entertain, and act on, applications for modifications of issued certificates of approval.

The committee has assigned classifications to the waters of the Yadkin, White Oak (including North, Northport, and New), Chowan, Roanoke, French Broad, Cape Fear, and Neuse River Basins, comprising 66.5 percent of the waters of the State.

Preparation of pollution survey reports, leading to assignments of classifications and pertaining to the Tar, Broad, Catawba, Pasquotank, Hiwassee, and Little Tennessee River Basins, have been substantially completed. It is anticipated that all waters of the State will have been classified by the end of 1961. Assignment of classifications is immediately followed by preparation of pollution abatement programs and action by the committee to effect accomplishment of such programs.

The committee's staff, heretofore known as the division of water pollution control of the State board of health, was transferred on September 1, 1959, as indicated above, in accordance with the Water Resources Act of 1959, to the stream sanitation and hydrology division of the department of water resources.

PROJECTIONS OF FUTURE DEMANDS FOR WATER AND WATER RELATED ACTIVITIES

Population projections.—The following table shows the percent increase of population served, water used, and the daily per capita use, between 1940 and 1950, for seven of the largest North Carolina cities:

[Percent increase]

City	Population	Average water used per day	Average gallons per capita
Charlotte	28.4	75.8	37.7
Durham	20.6	37.2	14.2
Gastonia	22.4	100.9	61.1
Greensboro	24.2	58.5	26.5
Raleigh	25.0	65.1	31.8
Winston-Salem	11.0	46.5	32.1
Wilmington	30.1	112.2	66.4
Average, 7 cities	28.8	70.9	38.5

Municipal water use.—Since the average gallons per capita for the seven cities was 75.6 and 100.6 in 1940 and 1950, respectively, it is estimated that the per capita demand in the seven cities for 1970 and 1980 will be 172 and 294 gallons per day, respectively. Similar calculations have resulted in estimates that 725 and 1,595 million gallons per day will be used for domestic and municipal water supplies in the State in 1970 and 1990, respectively.

Agricultural use of water.—Recent surveys have shown that, for domestic, industrial, and agricultural purposes, the State is using water at the rate of about 914 million gallons per day. It is estimated that, in 1975, about 660 million gallons per day will be needed for irrigation.

Water needs of industries.—A State agency made a survey in 1956 of use of water by industries. Answers to questionnaires were not made in many cases, and a large number of industries, especially those using ground water, do not know the amount of water which they use.

Electric energy.—In 1956, approximately 2,300 million gallons per day were used for cooling purposes by stream generating plants in North Carolina.

Navigation.—The Corps of Engineers, U.S. Army, has improved 1,100 miles of navigation channels in North Carolina, of which 41 miles are for deep-draft ocean vessels. Funds in the amount of $585,000 are available in the 1959 Public Works Appropriations Act to initiate the deepening of Morehead City Harbor and Beaufort Inlet from 30 feet to 35 feet. The district engineer, Wilmington district, is engaged in an investigation of the advisability of deepening the 28-mile channel, in the Cape Fear River from the Atlantic Ocean to Wilmington, from 34 feet to 40 feet. Several small navigation projects are also in the process of investigation. The condition and permanency of inlets, particularly Oregon, Ocracoke, Hatteras, and Drum Inlets, are of vital importance to the present and future economy of the coastal region in connection with commercial fishing. Inlets may be stabilized by the construction of jetties or the operation of sand-transfer facilities. Dredging performed in an inlet prior to its stabilization may prove to be inadvisable and uneconomical.

Flood control.—The great increase in losses from floods, along with the development and growth of the State, is creating a demand for alleviation and prevention, by intelligent engineering works, of conditions causing floods. Both upstream measures, including proper land-use practices and construction of storage or detention basins, and downstream measures, including channel improvement, bank protection, and flood control dams, can be advantageously used to alleviate and prevent damages.

The Corps of Engineers has completed the clearing and snagging of the Tar River between Tarboro and Rocky Mount, the Goldsboro flood control project, dikes in Bladen County along the Cape Fear River, clearing and snagging Trent River and New River, the Pasquotank River flood control project, and the John H. Kerr Reservoir in Virginia about 5 miles from the Virginia-North Carolina State line, which is preventing disastrous floods such as have occurred in the Roanoke River Basin in North Carolina. Funds are available in the 1959 Public Works Appropriations Act to initiate construction of a flood control reservoir on the Yadkin River about 8 miles upstream from Wilkesboro and to accomplish the engineering and design necessary for initiation of the improvement of about 15.2 miles of channels in Pantego and Cucklers Creeks, Pungo River Basin, for flood control and major drainage. The Congress has authorized the construction of a flood control reservoir on the Reddies River several miles above its confluence with the Yadkin River at Wilkesboro. The district engineer, Wilmington district, is engaged in investigations of the Cape Fear and Neuse River Basins, for flood control and allied purposes, and in investigations of several smaller flood control projects.

Water recreation.—There are, in North Carolina, 198 natural and 170 artificial lakes, along with its inlets, rivers, sounds, and 320 miles of shore line on the Atlantic coast, which provide water-recreation facilities for millions of people each year. There are 28 State and Federal parks, forests, and historical sites, including the Great Smoky Mountain National Park and the Blue Ridge Parkway, which are the most visited national parks in the United States. There are more than 70 lakes with recreational facilities in these parks and forests. Recreation is now of such importance that it is provided for, whenever practicable, in the planning of flood control, water supply, and hydroelectric reservoirs.

Fish and wildlife.—The State, realizing the recreational and commercial importance of fishing and wildlife resources, protects and improves these resources through the wildlife resources commission. The commission is particularly interested in the conservation of the striped-bass fishery and its annual spawning-ground on the Roanoke River immediately downstream from the Roanoke Rapids Reservoir being operated by Virginia Electric & Power Co. The wildlife resources commission, the State stream sanitation committee, and the department of water resources are collaborating with interested Federal agencies and representatives of water users in the lower Roanoke River Valley with a view to insuring that the license for Virginia Electric & Power Co., now pending before the Federal Power Commission, to construct a hydroelectric project, which would back up water from the headwaters of Roanoke Rapids Reservoir to the tailrace of John H. Kerr Reservoir, will insure that the striped-bass fishery is adequately protected and that municipalities, industries, and agriculturists downstream from the Roanoke Rapids Reservoir will be assured supplies of water which are proper in quality and adequate in quantity.

Trends in use of water for waste disposal.—Since the initiation of the pollution-abatement program in the summer of 1953 when the State stream sanitation committee, created in 1951, held public hearings in 5 cities throughout the State, 134 pollution-abatement projects have been constructed or are now under construction. The estimated cost of these projects is estimated at $42 million. In addition, 12 projects, estimated to cost $9 million, have been approved, and it is anticipated that their construction will be undertaken within the near future. The total value of projects being constructed annually has increased each year since the program began and is presently at the level of approximately $15 million per year. This level is expected to increase, particularly if Federal-grant allocations in accordance with the provisions of Public Law 660, 84th Congress, 2d session, are increased. In view of the fact that many municipalities which have prepared plans for pollution-abatement projects are not financially able to comply with State regulations regarding sales of municipal bonds, and whose ratings by the State stream sanitation committee are not sufficiently high to receive allocations by the committee from Federal grants, the committee has recommended to the general assembly that it establish a revolving fund for pollution-abatement construction loans to such municipalities.

Means of meeting future demands (new techniques)

Weather modification.—It is understood that the city of Greensboro, during the water shortage in 1955, entered into a weather-modification contract comprising the seeding of clouds with iodide crystals and that the results of operations under this contract were inconclusive.

I have no further statements to offer regarding "III, first phase, attachment 1." So far as I know, North Carolina agencies interested in conservation of water resources, have had no experience with conventional methods of vegetational management, evaporation reduction and seepage control, desalinization, etc. I think that the Senate Select Committee on Water Resources may obtain some benefit from the following statement by the director of water pollution control, State board of health, immediately prior to the organization of the department of water resources on September 1, 1959, regarding research needs.

> A sound and adequate program of basic research is essential to the development of any comprehensive program dealing with the complex problems inherent in proper water-resource management. The present lack of such research

leaves the Nation without scientific intelligence so desperately needed in the solution of many water-supply and pollution-control problems. Industry spends $7 billion or more annually for research relating to the development and production of new products, while the annual expenditure for research to develop and conserve water, the Nation's most important resource, is perhaps less than $7 million. Authorities indicate that research by the Federal agencies alone should be increased from present levels to a minimum of 25 million, as soon as possible, and that an equal amount should be spent by public and private organizations and industries outside of the Government.

There are many major areas of needed research in relation to water supply and water-pollution control. Some of the problems requiring research are listed below to emphasize this important need:

1. Development of higher degrees of waste treatment.
2. Toxicity of radioactive and synthetic chemical wastes.
3. Development of more efficient and less expensive methods of sewage and waste treatment.
4. Behavior of pollution discharges in estuaries and ocean waters.
5. Research training and facilities.
6. The fate of viruses in polluted waters.
7. The treatment and disposal of synthetic organic chemicals.
8. The effect of economic poisons upon man and the creatures of nature, and upon present water and waste-treatment plants.
9. Improved analytical procedures for measuring viruses, synthetic chemicals, and economic poisons in water and wastes.
10. Underground storage of water.
11. Reservoir evaporation control.
12. Complete removal of waste materials from water.
13. Weather modification.
14. Controlling radiological wastes.
15. Conversion of saline water to fresh potable water.

Limited research is now being carried out by the U.S. Public Health Service at its Sanitary Engineering Center in Cincinnati; however, the funds presently available for this work are totally inadequate. The same is true at the State and private-enterprise levels. With the fate of the Nation's water supply in the balance, need we quibble about the cost? We simply cannot afford such an expensive luxury. We must expand our water-supply and waste-disposal research, and such expansion should encompass and utilize the competencies of industry, universities, public agencies, private research institutions, and individuals.

The statement quoted immediately above, in which I concur, comprised part of an enclosure to a joint letter of August 12, 1959, from the chairman of the North Carolina State Stream Sanitation Committee to the Honorable John A. Blatnik and the Honorable Fred Schwengel, U.S. Representatives, in connection with a proposed White House Conference on Conservation of Water Resources.

II. SECOND PHASE

What has been done by the North Carolina General Assembly

In addition to creation of a department of water resources, which has assumed the responsibilities of the division of water pollution control of the State board of health and the water-resources responsibilities of the department of conservation and development, including both ground water and surface water, the 1959 session of the general assembly passed two other acts which will benefit the water-resources program of the State.

One of these acts authorizes local participation in reservoir projects constructed by the Corps of Engineers for the purpose of impounding water for present or anticipated future demand or need for municipal or industrial water in accordance with the provisions of the Water Supply Act of 1958 (title III, Public Law 85-500). It is understood that a local agency, comprising representatives of several counties in the Yadkin River Basin, has been organized and will agree to pay for the cost of provision of storage in the reservoir near Wilkesboro, referred to hereinbefore under "Flood Control," of water for present or anticipated future demand or need by municipalities or industries. This act will also apply to such reservoirs as may be constructed as a result of the investigations, presently in progress by the district engineer, Wilmington district, of the Cape Fear and Neuse River Basins. Three flood-control reservoirs in the Cape Fear River Basin and three flood-control reservoirs in the Neuse River Basin, are under study.

The other act created watershed-improvement districts which would have authority to assess landowners to be benefited by the improvements, in order to obtain funds to defray the costs of operation and maintenance of projects constructed under provisions of the Watershed Protection and Flood Prevention Act of 1954 (Public Law 566, 83d Cong., 2d sess.). The State conservationist, Soil Conservation Service, U.S. Department of Agriculture, has investigated, or has under investigation, 40 projects pertaining to this act. Of these projects, nine are in status to receive Federal funds to defray the proportionate share of the cost of installing works of improvement involving Federal assistance, providing that the local organizations concerned make agreements satisfactory to the Secretary of Agriculture for defraying costs of operating and maintaining such works.

What should be done by the State

The 1961 general assembly should give sympathetic consideration to creation of a revolving fund for loans to municipalities which are not in adequate financial status to sell bonds for the purpose of construction of sewage-treatment plants in accordance with pollution-abatement plans of the State stream sanitation committee.

Local agencies, authorized by the 1959 general assembly, should insure that storage of water for present or anticipated future demand or need by municipalities or industries is provided in flood control reservoirs constructed by the Corps of Engineers in the Yadkin, Cape Fear, and Neuse River Basins.

Watershed improvement districts should insure that funds to defray the costs of operation and maintenance of projects constructed under provisions of the Watershed Protection and Flood Prevention Act of 1954 are made available as soon as they are needed.

What should be done by the Federal Government

The Congress of the United States should be as liberal as is practicable in connection with grants to States under the provisions of Public Law 660, 84th Congress, 2d session, and in providing funds for research in relation to water supply and water-pollution control. The Congress should also give sympathetic consideration to the recommendations of the Senate Select Committee on Water Resources.

Conclusion of the statement of the director of the North Carolina Department of Water Resources

I believe that the work of the Senate Select Committee on Water Resources, and the results thereof, will be of great benefit to the people of the United States. I believe that when pollution-abatement programs, in accordance with adopted classifications of the waters of the State by the State stream sanitation committee, have been effected; when the Corps of Engineers has constructed, with provision of storage in accordance with the Water Supply Act of 1958, authorized reservoirs in the Yadkin River Basin and proposed reservoirs in the Cape Fear and Neuse River Basins; and when works of improvement under the provisions of the Watershed Protection and Flood Prevention Act, covered by applications for planning assistance processed or to be processed by the State conservationist, have been accomplished, the water-resources problems of the State of North Carolina between now and 1980 will have been substantially solved.

It has been a pleasure and a privilege to provide the committee with information regarding the status of water resources in North Carolina. Please let me know if I can be of further service to you or to the committee.

Sincerely yours,

HARRY E. BROWN.

NORTH DAKOTA

State of North Dakota,
Office of the Governor,
Bismarck, December 7, 1959.

Mr. Theodore M. Schad,
Staff Member, Senate Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

Dear Mr. Schad: Enclosed are copies of the report entitled "The Needs of North Dakota To Develop Its Water Resources" in our State. This is being submitted in connection with the request made by the Senate Select Committee on National Water Resources. In the event that you desire alterations or have further suggestions to make relative to the report, please feel free to contact me.

I again wish to thank Senator Kerr and the committee for holding the first hearing in the State of North Dakota. The hearing has increased the interest in the water resources of our State manyfold.

I also wish to thank you for the excellent work you performed in carrying out the committee arrangements in our State.

With kind personal regards.

John E. Davis, *Governor.*

The Needs of North Dakota To Develop its Water Resources for the Future

The basic industry in North Dakota is agriculture. The expansion and stability of the agriculture of the State depends to a great extent on the wise development and use of the available resources. Of these, water is of prime importance. Construction of the water resources projects proposed in North Dakota will not only benefit the State's agriculture but also will provide new opportunities for many more manufacturing and business enterprises. The need of and opportunities for water resources development in North Dakota are greatly influenced by the State's geography and climate.

The State of North Dakota covers an area of 70,655 square miles, of which approximately 700 square miles is water area. The land surface slopes generally to the east, with the highest point located in the southwestern corner and the low point in the northeastern section. Approximately 60 percent of the State—the western and south-central portions—is drained by the Missouri River and its tributaries. The remainder of the State drains into Hudson Bay in Canada through the Red and Souris Rivers. Most of the rivers and streams obtain their flows from the melting snows or runoff from rainfall on the plains area. The Missouri, which receives much of its flow from the melting snows in the mountains of Wyoming and Montana where it and its main tributary, the Yellowstone River, have their sources, is the only river flowing through North Dakota that can provide a reliable water supply.

North Dakota is a semiarid State. The rainfall pattern ranges from 15 inches on the average, annually, in the western portion to 21 inches, annually, in the extreme southeastern corner of North Dakota. Statewide the average annual precipitation approximates 17 inches. There is an extreme departure from these averages in various sections of the State each year. Drought periods frequently occur, often as intense as the one currently being experienced in approximately three-fourths of the State. As a result of these droughts, many ranchers are compelled to sell off their herds, as well as much of their foundation stock. The income of dryland farmers is severely reduced. The State's entire economy is so closely tied to the lifegiving rains, that it varies almost directly with the amount of rainfall received.

Topography of North Dakota is typical of that of the other States in the Great Plains area. Streamflow is erratic. An abundance of water usually occurs during the snowmelt. Frequently the flow of even the smallest streams attains flood proportions during the spring and during periods of heavy rainfall. This surplus water is too often discharged into larger streams where it aggravates and contributes to flood conditions.

North Dakota has long recognized the importance of a sound water resource development program. Many of the State's citizens have contributed generously in money, time, and effort to accomplish such a program.

During the 1930 drought period the need for greater emphasis on the development of the State's water resources became apparent. It was recognized that one agency should be responsible for the administration, control, and development of these water resources. In 1937 the State legislature recognized this need and created the North Dakota State Water Conservation Commission. The Governor serves as chairman of the commission and he appoints five other members who, along with the commissioners of agriculture and labor, compose the membership.

The commission was given authority and jurisdiction over the waters of the State and was made the responsible State agency for the development of water projects. It was given the authority and duty to investigate, plan, construct, and develop such projects throughout the State as were required and are within its ability.

Soon after the commission was organized in 1937 it recognized that there were several main problems connected with the water resources of our State with which they would have to deal. The solution of these was set out as the goals of the State's water resources program proposed by the commission. These goals still constitute the objectives of the North Dakota water resources program. They are:

1. Water for human needs.
2. Water for animal needs.
3. Water for irrigation.
4. Water for industry other than that available through municipal supplies.
5. Water for recreation and wildlife.
6. Control of water to avert flood damages.

Throughout the years the commission has been confronted with two main problems in its efforts to attain these objectives. These are the recurring drought conditions and the ever-increasing demand for water.

Ever since 1902 the State has cooperated with the Hydrographic Branch of the U.S. Geological Survey in maintaining stream-gaging stations and gathering and compiling streamflow data. These records emphasize the fact that the Missouri River is our only reliable source of surface water. They show that all other streams in the State, at one time or another, have practically no flow. This condition occurs during the drought periods when the requirements for water are at a maximum. The graph on page 268 depicts the flow of typical North Dakota streams.

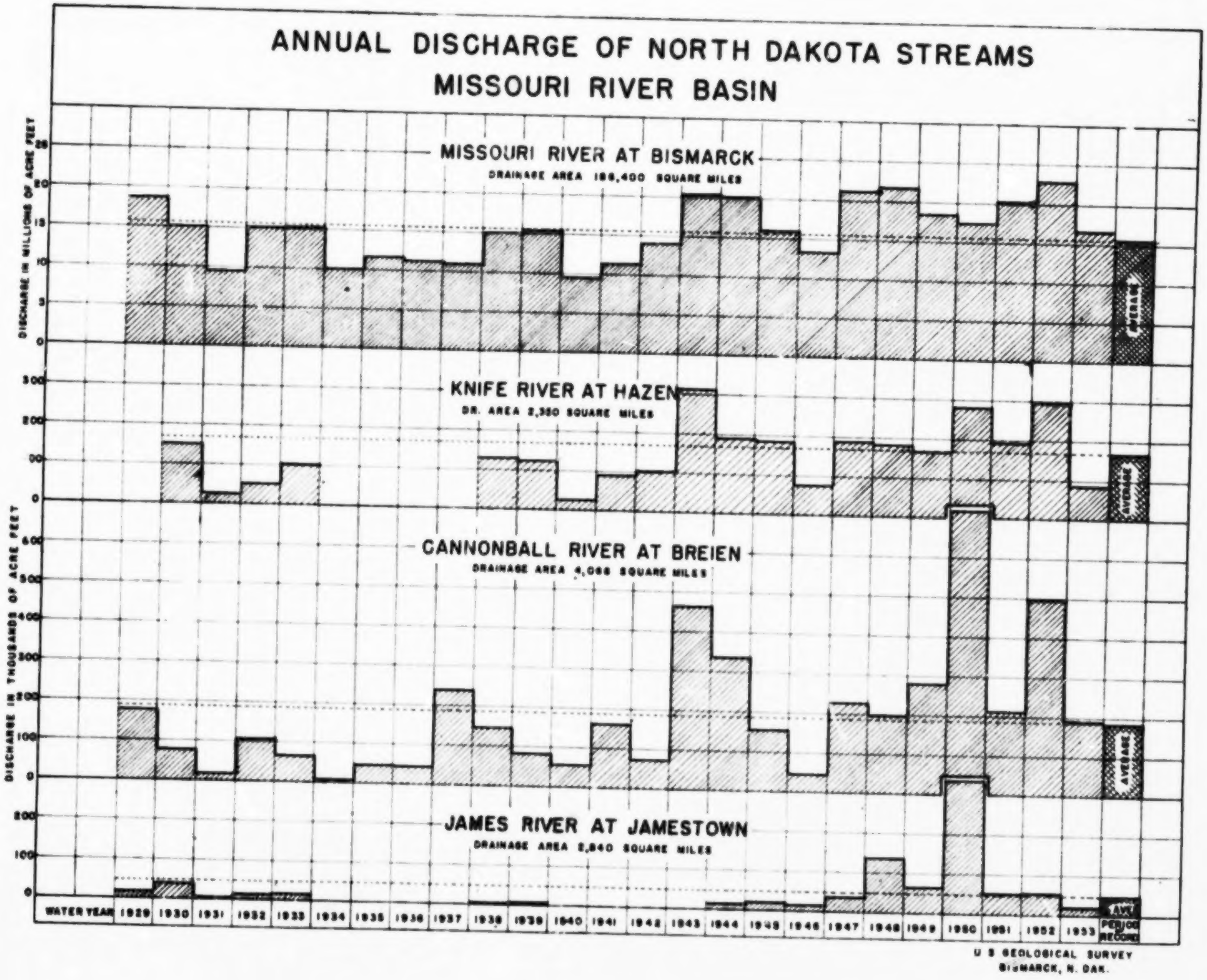
Because of the wide fluctuations in the flows of practically all North Dakota's rivers, the necessity of storing water for our present and future uses must be recognized. This must be done during the periods of high runoff. A great deal of effort has been put forth by Federal, State, and local agencies and individuals in the construction of multiple-purpose reservoirs to accomplish this storage. Much more remains to be done.

Table I lists nine reservoirs having an active storage of 3,084,650 acre-feet for use in North Dakota. These have been constructed by State and Federal agencies in cooperation with local interests.

These reservoirs store floodwaters to provide a valuable water supply in the areas in which they are located. They also serve other purposes such as power generation, recreation, fish and wildlife enhancement, and many other uses.

In addition to the large multiple-purpose structures in North Dakota, there are approximately 1,200 small dams that have been built by State and Federal agencies in cooperation with local groups. Since 1943 the commission, with the limited funds it has had available, has sponsored a program of construction, reconstruction, and maintenance of these small dams. These structures are valuable for municipal water supplies, recreation, and other purposes.

North Dakota's water resource development program also includes ground-water investigations which are conducted by the commission in cooperation with the Ground Water Branch of the U.S. Geological Survey. These investigations have located some excellent aquifers in various sections of the State. Because of the limited surface water resources, almost all North Dakota municipalities depend on ground-water sources for their municipal supplies. The commission's ground-water program, therefore, has been directed to the end of locating the best ground-



ANNUAL DISCHARGE OF NORTH DAKOTA STREAMS
MISSOURI RIVER BASIN

U S GEOLOGICAL SURVEY
BISMARCK, N. DAK.

TABLE I.—*Reservoirs constructed in North Dakota through the cooperation of Federal and non-Federal agencies*

Name	Location	Cooperating Federal agency	Capacity in acre-feet	Use
Lake Darling	Northwest	U.S. Fish and Wildlife	112,000	Wildlife refuge and some flood control.
Garrison Dam	do	Corps of Engineers	24,000,000 (2,640,000 now reserved for North Dakota).	Municipal water, irrigation, flood control, navigation, and power.
Dickinson Dam	Southwest	U.S. Bureau of Reclamation	9,500 flood; 4,000 active	Irrigation and municipal.
Heart Butte Dam	do	do	428,000 flood; 225,000 active	Flood control and irrigation.
Oahe Dam	do	Corps of Engineers	23,000,000; reservoir in South Dakota extends into North Dakota.	Municipal water, irrigation, flood control, navigation, and power.
Jamestown Dam	Southeast	U.S. Bureau of Reclamation	220,000 flood; 30,000 active	Flood control, irrigation, and municipal.
Baldhill Dam	do	Corps of Engineers	116,500 flood; 70,000 active	Flood control and municipal water.
Lake Traverse	do	do	137,000 flood; reservoir in South Dakota extends into North Dakota.	Flood control.
Homme Dam	Northeast	do	6,700 flood; 3,650 active	Municipal water supply.

water supplies for many municipalities. In recent years, however, it is expanding to determine the location of aquifers that will be suitable for irrigation development and industrial use. The cooperative ground-water investigation program has been underway since 1945. Many municipalities and a number of irrigators have obtained water supplies sufficient to meet their demands as a result of the information obtained and made available through surveys.

The last legislature made it possible to accelerate the ground-water investigation program by making available $50,000 a year, which will be matched by Federal funds. This expanded program will provide an opportunity to catalog approximately 50 percent of the ground water in the State by 1980.

The commission has estimated that throughout North Dakota ground-water supplies may provide approximately 250 million gallons of water daily. This would support an additional 166,000 people based on our national average per capita consumption of 1,500 gallons per day, which includes the combined use of water in homes and high-water-consuming industries. The commission hopes to obtain an overall knowledge of the State's ground-water resources to assist in effectively directing the optimum development of these resources for use in the entire State. Such information will also enable the establishment of effective conservation and administrative measures which may become necessary.

Three-fourths of an inch of our annual precipitation of 17.11 inches escapes in the form of runoff and leaves the State. This averages 2½ billion gallons of runoff per day. Such runoff and the intermittent nature of our streams make necessary the impounding of precipitation for regulated use. If only 10 percent of the runoff were impounded, it would provide us with storage capabilities which could be made available for public consumption at a rate of 250 million gallons per day. Such stored water would be sufficient for 170,000 people, based on the national water-use average.

In North Dakota water for irrigation is a primary need. Approximately 96,000 acres of land are being irrigated in North Dakota at present. A considerable portion of this irrigation is being conducted on a limited basis as the streams on which the irrigation is dependent are intermittent in flow. Supplemental water in the amount of 45,000 acre-feet is needed for this acreage. Even with a limited water supply these areas are aided materially by the partial irrigation possible, because it provides ranchers an opportunity to produce some feed to hold over foundation stock during drought periods. Most of these projects have been developed with private capital and represent a considerable investment on the part of the individual.

There are potential projects throughout the State that when developed will greatly benefit their localities as well as the State and Nation. The largest of these projects is the Garrison diversion unit. The proposed Garrison diversion unit, a multiple purpose project, will, when it becomes a reality, care for many of the present and future water problems in a large portion of central and eastern North Dakota. This unit is a renamed and revised segment of the comprehensive plant for the Missouri River diversion in North Dakota. It was authorized as an initial unit of the Missouri River Basin project in the

1944 Flood Control Act, but it is felt that some modifying legislation may be needed.

The principal benefit to North Dakota from the project will be from irrigation. Over a million acres of good agricultural land, that now badly need a water supply, can be served under this project. In addition an estimated 50 cities and towns ranging in size from a few hundred to over 40,000 that presently have critical water supply problems can obtain the assured supply they need to prosper and grow. The project will also provide numerous new recreational opportunities in an area where such facilities are now limited or nonexistent and will provide for 62 new fish and wildlife areas comprising over 72,000 acres of water and 157,000 acres of natural habitat.

Several alkaline lakes will be restored and transformed into fresh water lakes enhancing their use for municipal and industrial use as well as for recreational purposes. The flow of numerous river streams that course the project area will be materially augmented by the irrigation return flows that drain into them.

Studies made by the North Dakota Agricultural College show that North Dakota's benefit from the proposed Garrison diversion unit will come from the expanded livestock enterprise that will develop. With irrigation, stable feed supplies will be available to sustain beef, dairy cattle, hogs and sheep. North Dakota's stockmen will become the source of feeder cattle and feeder lambs for farmers in the irrigation project. Calves will be marketed twice—once as feeders and again as finished animals. In the past only a small number of North Dakota's calves have been fed in the state. Irrigation's demand for full use of farm labor provides a basis for a splendid hog industry. The suitability of irrigated farms for small sheep flocks will help insure income for many of tomorrow's irrigators.

Table II indicates the irrigation development (anticipated in North Dakota that will fit in with the agricultural needs of the State and Nation) recommended to meet the foreseeable agricultural needs of North Dakota and the Nation.

The North Dakota State Water Conservation Commission, on June 14, 1957, adopted a resolution reserving and withdrawing from appropriations 2,640,000 acre-feet of water from the Missouri River for use in connection with the Garrison diversion unit. This we feel will assure us a portion of our rightful share of stored water in North Dakota.

TABLE II.—*Development of irrigation in North Dakota*

Year	Individual projects (acres)	Group projects (acres)	Garrison diversion project (acres)	Total (acres)
1950	35, 000	37, 000	----------	72, 000
1952	37, 000	37, 000	----------	74, 000
1954	40, 000	38, 000	----------	78, 000
1956	45, 000	39, 000	----------	84, 000
1958	53, 000	39, 000	----------	92, 000
1959	56, 000	40, 000	----------	96, 000
1960	62, 000	40, 000	----------	102, 000
1965	82, 000	50, 000	----------	132, 000
1970	102, 000	60, 000	6, 000	168, 000
1975	117, 000	75, 000	68, 000	260, 000
1980	132, 000	90, 000	211, 000	433, 000
1985	147, 000	110, 000	339, 000	596, 000
1990	162, 000	130, 000	392, 000	684, 000
1995	182, 000	150, 000	456, 000	788, 000
2000	202, 000	180, 000	615, 000	997, 000
2005	222, 000	210, 000	783, 000	1, 215, 000
2010	242, 000	250, 000	909, 000	1, 401, 000
2015	262, 000	290, 000	982, 000	1, 534, 000
2020	282, 000	320, 000	1, 000, 000	1, 602, 000
2025	302, 000	350, 000	1, 007, 000	1, 659, 000

It will be necessary to obtain, through storage and ground water supplies, an additional 324,000 acre-feet to meet the irrigation requirements by 1980 for irrigation projects other than the Garrison diversion unit. Table II has been extended to show our irrigation requirements beyond the year 1980 up to 2025, when it is estimated the Garrison diversion unit will attain full development.

Thus it appears that the orderly development of the three major water resource possibilities, the Garrison diversion unit, ground water aquifers and the storage of runoff water, would provide for a population increase in excess of 400,000 people in North Dakota by the year 1980. Much careful planning will be required to develop North Dakota's water resources to the extent that it will make this population increase possible.

Table III "Water resources for the future", lists some of the proposals in the State that are receiving consideration for development within the next 20 years.

In summing up the construction expenditures required to achieve an effective water program to meet the growing population requirements by 1980, they would be as follows:

1. U.S. Bureau of Reclamation	$637, 242, 000
2. U.S. Corps of Engineers	101, 000, 000
3. Soil Conservation Service	39, 850, 000
4. U.S. Wildlife Service	10, 250, 000
5. Non-Federal	114, 050, 000
Total	902, 392, 000

In addition to the construction expenditures the above agencies would need $17,500,000 for planing, investigation, and surveys. Recreation needs should be met through funds in the amount of $2,500,000 provided by the various construction agencies.

An important feature of every water resources project is the new and improved recreational facilities that develop. North Dakota is particularly cognizant of this benefit for without the small and large dams that have been constructed here the State would be practically devoid of recreational facilities. The extensive and expanding use of reservoirs for swimming, boating, fishing, camping and other purposes by the people of the State testifies to the value of these projects for recreation. Greater recognition to recreation as a benefit from water resources projects should be provided when the feasibility of water resources projects is being determined. In this connection S. 159 often referred to as the Kerr bill merits strong support.

In general, the relationship between the State and Federal agencies concerned with water development is very good. There are, however, opportunities for improvement on the part of all. One such improvement concerns preliminary planning. Much information is available pertaining to water in the office of the North Dakota State Water Conservation Commission, the State health department and the State game and fish department.

TABLE III.—*Water projects for the future*

Name	Location	Implied construction agency	Capacity in acre-feet	Principal use	Estimated cost
Broncho Dam	Southwest	U.S. Bureau of Reclamation	60,000	Irrigation, municipal	$12,400,000
Cannonball Dam	do	do	80,000	do	13,300,000
Mott Dam	do	do	44,700	do	9,242,000
Thunderhawk Dam	do	do	43,400	do	11,000,000
Green River Dam	do	Corps of Engineers		Municipal recreation	3,000,000
Bowman-Haley Dam	do	do	20,000	Municipal, flood control, recreation.	3,000,000
Bullion Butte Dam	do	U.S. Bureau of Reclamation	250,000	Irrigation, municipal	32,500,000
State water projects	do	State water conservation commission	106,000	Municipal, irrigation, recreation.	6,000,000
Missouri bank stabilization	do	Corps of Engineers	150,000	Erosion control, recreation	36,000,000
Municipal water supplies	do	Cities		Municipal	10,000,000
Flood protective works	do	do		Flood control	5,000,000
Wildlife projects	do	U.S. Wildlife Service		Recreation	2,000,000
Souris River Dam	Northwest	Corps of Engineers	430,000	Flood control, municipal, wildlife.	12,000,000
Little Muddy project	do	North Dakota State Water Commission.	14,000	Irrigation, recreation	100,000
Ground-water development	do	U.S. Bureau of Reclamation and State water commission.		Municipal, irrigation	12,000,000
Small reclamation projects	do	do	14,400,000 3,600,000	Irrigation	18,000,000
State water projects	do	State water conservation commission.	80,000	Municipal	6,000,000
Municipal water	do	Cities		do	25,000,000
Upper Souris flood control	do	Corps of Engineers		Flood control	1,000,000
Flood protective works	do	do		do	4,000,000
Turtle Mountain development	do	U.S. Wildlife Service and State	2,250,000 750,000	Recreation	3,000,000
Wildlife projects	do	U.S. Wildlife Service		do	2,000,000
Warwick Dam	Northeast	U.S. Bureau of Reclamation	535,000	Irrigation, municipal, recreation.	8,900,000
Pembilier Dam	do	Corps of Engineers	150,000	Flood control, municipal, irrigation.	14,000,000
Kellys Lake	do	Game and fish water commission		Recreation	100,000
Forest River watershed	do	Soil Conservation Service		Flood control	4,000,000
Tongue River watershed	do	do		do	5,000,000
Park River watershed	do	do		do	5,000,000
State water projects	do	State water commission	75,000	Municipal	6,000,000
Municipal water	do	Cities		do	10,000,000
Flood protective works	do	Corps of Engineers, Soil Conservation Service, and local agencies.		Flood control	30,000,000
Wildlife projects	do	U.S. Wildlife Service		Recreation	2,000,000
Pipestem Creek	Southeast	Corps of Engineers	80,000	Flood control, municipal	8,000,000
Tewaukon watershed	do	Soil Conservation Service		Flood control	1,000,000
Elm River watershed	do	do		do	1,600,000
Wildrice watershed	do	do		do	1,250,000
Ground-water development	do	U.S. Bureau of Reclamation and State water commission.		Municipal, irrigation	10,000,000
Swan-Buffalo Creek watershed	do	Soil Conservation Service		Flood control	2,000,000
Municipal water	do	Cities		Municipal	10,000,000
State water projects	do	State water commission	10,000	do	6,000,000
Flood protection	do	Corps of Engineers and local agencies		Flood control	30,000,000
Wildlife projects	do	U.S. Wildlife Service		Recreation	2,000,000
Garrison diversion unit	Central and Eastern.	U.S. Bureau of Reclamation		Irrigation, municipal, and industrial.	519,000,000
					902,392,000
Recreation	Statewide	Various			2,500,000
Planning, investigation, and surveys.	do	do			17,500,000
Total					922,392,000

On some occasions Federal agencies make investigations in the State without an effort to obtain information at the State level. This adds to the cost of the investigations. The commission maintains a current record of water rights. In some cases projects are constructed without an attempt being made to check on water rights and honor their integrity. Immediate Federal legislation is needed (1) that will clearly state that the Federal Government shall not be deemed to have or acquire any water rights as a result of the reservation or withdrawal of public land; (2) that will require compliance with State water laws by all Federal agencies, licensees or project beneficiaries; and (3) that will adequately safeguard all water rights established under State laws against the Federal agencies and their licensees.

Some projects have been promoted at a local level by representatives of a Federal agency without contacting the appropriate State agency. The momentum behind such projects is sometimes so great that it endangers other more meritorious projects in the same area. This, to some extent, may be a condition for which the State is partly at fault because it has not provided the commission with a sufficiently large staff to attend all the field meetings Federal agencies are holding involving water projects.

In at least one instance a study report was not submitted for public inspection when a review by the sponsoring citizens was much desired. The flood conditions that may occur from this omission might conceivably result in a major catastrophe. The State water conservation commission is anxious to cooperate with any Federal agency contemplating activity in the water resources field and desires to be contacted in the planning stage. The commission has cooperated with all agencies in permitting them the use of water records, topographic maps, and ground-water information for any projects which might be of benefit to North Dakota. Through properly coordinated efforts on the part of Federal and State agencies the development of water resources projects to serve all anticipated needs can result rather than the design and construction of a project to serve only the need of interest to one particular agency.

In the Small Projects Act it is proposed that the States or irrigation districts who construct projects under that act will be required to pay for any previous Federal planning that has gone into such a project. We believe any previous surveys and investigations should be made available without cost to the project.

The construction of stockwater ponds and watering dugouts is a very commendable practice; however, there are instances where the spacing of such reservoirs creates a situation where much more water is impounded than is necessary. It is proposed that immediate research be undertaken to determine optimum spacing of such reservoirs and that the use of evaporation suppressants thereon be studied in order that evaporation can be minimized.

Someday, in the not too distant future, good reservoir sites for use in storing water will be at a premium. Great care should be exercised on the part of State and Federal agencies to size the reservoirs they are now constructing and planning to accommodate the storage of the greatest feasible quantity of water possible.

It is felt that greater care should be exercised in determining the quantity of water available in intermittently flowing streams used in developing private irrigation projects. The burdening of prospective irrigators with irrigation equipment which they cannot efficiently use may injure an otherwise worthwhile program.

A considerable amount of work is conducted in North Dakota by the State in cooperation with the USGS. The State is required to use its funds to match Federal administrative costs in Washington, D.C. This takes as much as 13 percent of our funds. Federal policy will not permit us to include our administrative charges in the matching fund. It is hoped that your committee might consider the exclusion of such Federal service charges from State matching funds or recommend that some other committee study this matter. In our cooperative work with the USGS Topographic and Ground Water Branches usually a 4-year period is required for completion of reports and maps. This often delays the construction of proposed projects of an emergency nature.

In North Dakota the Missouri River has been tamed and controlled by the Garrison Reservoir, a virtually completed part of this basin project. The people of North Dakota now look forward to the chance to put a small part of the water stored in the Garrison Reservoir to work. The Garrison diversion unit represents North Dakota's primary interest in the Missouri River development. This unit is the only prospect for bringing water to 25 counties representing more than half of our State's area and population. North Dakota, along with the other Missouri Basin States, has consistently advocated and worked for the full development of the water resources of the Missouri Basin. It is satisfying to note that the mainstem flood control, which had to come first, navigation its byproduct, and power the principal income producer, are all so well along toward completion. The impressive progress that has been made during the past 14-year period was accomplished through the traditional pattern of government organization.

We have a more personal reason to rejoice in the work that is now completed. It now opens up at least the opportunity to develop much desired irrigation in many areas in our State. The State's sacrifice of 548,000 acres of land, and over 200 ranches and farms to provide space for the Oahe and Garrison Reservoirs can now be partially replaced through the development of irrigation that will benefit the State and the Nation. Approximately 200,000 acres of that bottomland used for reservoir purposes possessed low-cost irrigation potential because in most instances it is underlain by an underground aquifer. Now this low-cost potential development is lost forever.

The people of North Dakota are anxious to push the Missouri Basin project on to completion. Once a river development is started, everyone profits from rapid completion. Delays and postponements cost money and defer benefits. Potential irrigators in North Dakota have long anticipated that the start of construction on the Garrison diversion unit would be in fiscal year 1963. We are hopeful this target date will be met.

The development of our water resources is the key to the growth and prosperity of North Dakota. New and expanded opportunities that will result through a sound water resources program will encourage our youth, our most precious resource, to stay in the State, reversing the trend of recent years.

DECEMBER 4, 1959.

OHIO

STATE OF OHIO,
OFFICE OF THE GOVERNOR,
Columbus, September 14, 1959.

Hon. ROBERT S. KERR,
U.S. Senate, Washington, D.C.

MY DEAR SENATOR KERR: In response to your letter of June 23, 1959, I am mailing you copies of "Ohio's Water Resources Plans, Programs, and Problems," for the information of the Senate Select Committee on National Water Resources.

Sincerely,

MICHAEL V. DISALLE, *Governor.*

OHIO'S WATER RESOURCES PLANS, PROGRAMS AND PROBLEMS

General

Ohio ranks second in the Nation in value added by manufacturing but ranks first in the industrial use of fresh water. It ranks fifth in population and fourth in the use of water for public water supplies. In land area Ohio ranks 36th in size among the States. The land area on which water can be obtained is relatively small for the population and industry which must be served. Water withdrawn for use is 46 percent of the volume of runoff originating on the land surface of the State. Only New Jersey exceeds this percentage among the nonirrigation States.

Ohio would have a precarious situation in meeting its water needs without the waters of Lake Erie for use by the northern third of the State within the Lake Erie Basin and the Ohio River on the south.

Quantities of water used

An inventory of water use conducted by the Ohio Division of Water in 1955 indicates the following quantities by type of use:

	Million gallons per day
Manufacturing (including thermal power generation)	10,384
Municipal use	966
Supplemental irrigation	83
Rural use	139
Total	11,572

An analysis of water use by source of supply is as follows:

	Million gallons per day
Streams (inland)	4,945
Lake Erie	2,642
Ohio River	3,236
Underground aquifers	749

Quantities of water available

Water can be withdrawn in practically unlimited quantities from Lake Erie requiring only its transportation to inland places of use within the Lake Erie Basin. Because Lake Erie is part of international boundary waters it is not permissible to divert its waters outside the Lake Erie Basin. Even with this limitation Lake Erie water can be made available in 29 percent of the land area of the State in which reside 41 percent of its people.

Quantities of water available from flow of the Ohio River are also large. Degradation of quality of water by upstream users and from coal mine drainage present a problem of continuing concern.

The natural flow of streams within Ohio, during periods of low flow, cannot sustain the industrial demand for water without considerable reuse of water. Intensive use requires that the natural low flow be augmented by providing reservoirs to store floodwaters for later release when streamflow is insufficient. This has been done in some of the highly industrialized areas distant from Lake Erie or from the Ohio River. The Mahoning River with nearly 10 percent of the Nation's steel capacity is an example of a river developed almost to its ultimate by reservoir storage in order to supply the almost unquenchable thirst of steel mills and powerplants.

Underground water, although comprising only 6 percent of industrial and domestic water use, is a highly important component of Ohio's water assets. Water from underground is prized for its clarity, coldness, freedom from pollution, and its large holdover capacity during drought periods. The Dayton area, the most heavily pumped underground-water area in the State, has developed a whole complex of industries dependent on this resource. There is a similar area in the Mill Creek Basin adjacent to Cincinnati.

These underground sources continue to supply heavy industrial requirements without any progressive depletion.

Methods for increasing available water

Development of water resources requires a knowledge of flow regimen of streams, chemical and physical quality of waters, the occurrence and extent of underground reservoirs, topographical, soil and foundation aspects of reservoir sites, etc. This implies a complete inventory and appraisal of water and related resources. Ohio is conducting such a water inventory together with an accelerated program of topographic mapping and soil surveys. These are fundamental in any successful water management program to provide for future population and industry.

Rivers may be made more usable by reservoir storage making the flow more uniform. Low flows are increased by release of stored water. High flows, floods, are reduced. Reservoirs thus can serve a dual purpose. Much more effort in river regulation and control is required for future growth.

Lake Erie and the Ohio River can be made more useful by the extension of pipelines for supplying water farther inland. Lake Erie water is now piped a maximum of about 20 miles and Ohio River pipelines, except possibly in the Cincinnati water system, much less. It is considered feasible that the northern third of Ohio will eventually be served by a network of water pipelines extending to the southern limits of the watershed.

Water pipelines will undoubtedly be extended northward from the Ohio River. Here, however, reservoir sites on tributary streams are more feasible and must be weighed costwise against pipelines.

Water in the streams of Ohio is used over and over in its downstream journey. At times the total flow of the Mahoning River has an eight-times reuse throughout its length.

Reuse of water requires that pollution abatement measures be rigoriously enforced. Pollution prevention is a highly effective means of stretching the available water supply. Much has been accomplished but much remains to be done.

Water from underground sources must also be carefully managed for most efficient use. An inventory system consisting of gages on wells in the principal underground aquifers showing fluctuations of the water table is imperative. Progressive declines in water tables can thus be detected before situations become acute and withdrawals by pumping can be adjusted to natural recharge.

Underground water sources are subject to pollution although not as readily as streams. Oil and gas operations and salt mining by water injection are common methods of underground water pollution. Needless to say we cannot permit such a destruction of a valuable water resource.

Underground sources of water are not visible from the surface. They are found by underground exploration, either by drilling or by geophysical methods. In Ohio there are undoubtedly underground aquifers which have not yet been discovered. An extensive drilling and geophysical program should yield new sources of low-cost water which if managed properly will yield high-quality water indefinitely.

Water development problems

Water problems in Ohio have been represented by a "water problem triangle," each vertex symbolizing the problem; namely, physical, institutional, and economical.

The physical problem involves the query, What water do we have? Shall we build dams, drill wells, build pipelines, etc.?

The institutional problem relates to legality, what kind of administering body is needed, will a project conflict with other plans and programs, etc.

The economic problem is of concern as to costs, ability to finance, are people willing to pay the cost, etc.

Of the three problems in Ohio, at present at least, it appears that the latter two, institutional and economic, are the most difficult to resolve. Laws and institutions are often almost insuperable hurdles. Financing is a formidable obstacle. Additional tax levies are resisted. Revenue-bond financing often is difficult in that it is highly conservative in projecting future growth in water use and revenue. Revenue bonds are not speculative investments involving risk based on anticipated growth, and yet water resources projects for economical and full development must project revenues based on growth of population and industry.

The role of Federal and State Government in water resources

In this section it is proposed to enumerate not necessarily in order of importance the respective roles of Federal and State Government in achieving needed water management and development. It should be realized that both Federal and State water policy are in a state of flux with no clearly defined demarcation in their respective roles. In the recent past many States practically abdicated their role in water resources.

Presently, however, a number of States have created strong water agencies which are assuming a positive State role as well as effective cooperation and partnership with the Federal Government in water resources development.

Fields of water resources in which the Federal and State of Ohio are engaged are described in the following with a statement of their effectiveness.

Water resources basic data programs

Streamflow data collection ground water evaluation, topographic mapping, and chemical and physical quality of water programs are cooperative with the Geological Survey, U.S. Department of the Interior, on a dollar-matching basis. These are longstanding programs which have been eminently successful for the comparatively small investment involved. Principal difficulty has been the lack of appropriations at times by the Congress to meet all State offerings.

Basic data programs on precipitation data collected by the Weather Bureau has been largely a Federal function which has been and will continue to be indispensable to all water resources programs.

The Soil Conservation Service and the Agricultural Research Service have and are collecting valuable data on water resources.

The basic data program needs expansion by both Federal and State agencies as the need for water grows. This is the bedrock on which a sound water development program is founded.

Flood control

Flood control has become largely a Federal function. Ohio through the Miami Conservancy District built the first basinwide system in the Nation before the Federal Government assumed any share in flood control. Since that time a number of other flood-control developments have been made in the State. In most of them the State or local government has assumed a portion of the cost. It is believed there should be participation in such costs.

The State should assume a greater part in the conception and design of flood-control projects rather than tacit approval when such conception and design is completed.

Present and future need for water demands that water supply be incorporated into flood control reservoirs even though the need may not be presently apparent. Otherwise limited reservoir sites will be preempted for a single purpose, whereas maximizing the development often could include water supply. Financing during the interim period of water supply nonuse poses problems.

Small area flood control under Public Law 566 is being widely investigated in the State. Many investigations have shown lack of economic justification. The law has features which make it difficult to administer. A number of investigations are underway which may tend to clarify some of these difficulties. Relations with the Soil Conservation Service have been excellent.

Drainage

Major drainage in the past has been a function of counties, later amended to districts embracing more than one county. Drainage in northwestern Ohio is probably as intensive as anywhere in the Nation. No Federal major drainage projects have been constructed in Ohio. Although some projects have been surveyed, none showed economic feasibility. Major problems of drainage relate to lack of maintenance, which is a result of local apathy.

Water recreation

Ohio is in need of more water recreation areas. Almost all flood control reservoirs offer opportunities for water recreation. In the past the benefits from recreation have been given little consideration. Benefits from recreation should be evaluated based on the intensive use of present flood-control reservoirs in the State.

In summing up the job ahead a few things stand out as paramount. In the field of State-Federal cooperative programs basic hydrologic data collection and mapping are in need of much acceleration. Water development programs on a State-Federal basis need greater clarification especially in dual purpose developments of flood control and water supply. On the State and local level new political institutions are needed to develop and finance water resources on a watershed or regional basis rather than on the basis of local political boundaries.

OKLAHOMA

November 16, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: In compliance with your letter of June 23, 1959, we submit herewith a statement to your Select Committee on Water Resources Problems which we hope will be of assistance to your committee in preparing a report for the overall water needs of the Nation by the year 1980. I have prepared this statement with the assistance of the Oklahoma Water Resources Board and other State agencies that are directly concerned with water development and management. Obviously, the condensation, as requested by you, has omitted considerable detail.

The State of Oklahoma has made many detailed studies of the various aspects of its water resources; the most recent studies were prepared by the Bureau of Water Resources Research of the University of Oklahoma entitled "Water—Oklahoma's Number One Problem" and "Water—Facts and Futures" are attached as they bear directly on the problems at hand. These studies, under the editorship of Prof. George Reid, consultant to the Oklahoma Water Resources Board, represent data from contributions from our outstanding water engineers, economists, scientists, lawyers, etc.

The State of Oklahoma and its agencies stand ready at all times to lend your committee every possible assistance in its herculean task. If additional detail is desired, please feel free to call on us.

Respectfully submitted.

J. Howard Edmondson, *Governor.*

Oklahoma considers water essential to its continued growth. It has an excellent labor market and abundant raw materials with the availability of water becoming increasingly the controlling factor.

Over the years, Oklahoma has created State agencies with duties and responsibilities in water resource use, regulation, and development. The 25th legislature established a water resources policy and the Oklahoma Water Resources Board with factfinding, planning, and coordinating responsibilities.

The State universities and volunteer organizations such as the Arkansas River Basin Association are actively participating in water resources development.

Oklahoma's water resources vary widely in quality, quantity, and areal distribution. Modification of this wide variation is her basic problem. The following materials briefly outline water facts and futures under the broad headings of surface water, flood control, ground water, water quality and stream pollution control, future water requirement, and factors of future importance.

Surface water

The normal annual precipitation in the headwaters of the Mountain Fork River in southeastern Oklahoma is 50 inches of which 40 percent occurs as runoff while in the Panhandle area, where the normal annual rainfall is 17 inches, runoff averages only 1 to 2 percent. The extremes may range as high as 200 to 300 percent of the long-term average and down to 0 to 30 percent.

There are two river basins in Oklahoma. The Arkansas occupies the northern two-thirds of the State and the Red River the southern one-third. At Fort Smith, as the Arkansas leaves Oklahoma, the annual average flow is 21,990,000 acre-feet according to the U.S. Geological Survey reports. Approximately 10,500,000 acre-feet of this originates in Texas, Missouri, Kansas, and Arkansas. This leaves about 11,500,000 acre-feet originating in the Arkansas Basin in Oklahoma. The average annual flow out of Oklahoma from the Red River system totals about 11,900,000 acre-feet. Of this, 275,000 acre-feet originates in Texas, so that 11,625,000 acre-feet can be considered as originating in Oklahoma. This gives a total in round numbers of 23 million acre-feet of water in the average year from our surface supplies in this State.

Thus, roughly 18 percent of the precipitation represents the upper limit of surface and ground water available for development in Oklahoma.

There is at present approximately 4,500,000 acre-feet available storage in Federal lakes in Oklahoma, and another approximate 5 million acre-feet authorized. These are multiple-purpose reservoirs.

Flood control

Serious floods in 1957 and then even more serious flooding in 1959 have shown up areas of serious deficiency in the program to control floods now authorized in Oklahoma.

Taking first the Arkansas Basin, we find that there is not a single authorized project on the Cimarron River. Several projects have been studied, but economic justification has always been lacking. The site at Spurgeon and Black Mesa are so far upstream that their effectiveness in controlling floods such as occurred in 1957 and 1959 would be minimized in the lower reaches of the stream. The Englewood project could make a contribution to control floods on this stream. However, for purposes of controlling the water in the eastern part of the basin and protection of Guthrie, the project at Crescent would appear to offer the best chance of developing economic feasibility.

While the lower part of the Arkansas River will receive the protection that will be afforded by the Keystone Reservoir, the portion on the main stem above Keystone is unprotected, except for the Salt Plains Reservoir on the Salt Fork. Projects on the Ninnescah and Chikaskia Rivers should be reexamined in the light of the recent floods. Studies on the Kaw Reservoir should also be expedited because this project can serve both in a flood control capacity and as a regulating reservoir, which will enhance the power production potential at Keystone. Studies now in progress on tributaries of the Verdigris River which join the main stem below the Oologah Dam should be expedited.

Serious flooding resulted this year from uncontrolled flows of Bird and Hominy Creeks. It is believed that these two streams will have to be controlled before navigation to Catoosa can be uninterrupted. The Bird-Caney Verdigris study is now underway, and it includes reservoirs at Skiatook and Avant,Copan and Sand Creeks, which will probably solve this problem, at least partially in this section of the valley. The four projects in the upper part of this valley in Kansas, at Strawn, Council Grove, Marion, and Cedar Point, will be helpful, but they do little to offset the tremendously large drainage between the Strawn Reservoir and the headwaters of Pensacola. Projects on the Spring and Elk Rivers would be helpful.

In the Red River system every effort should be made to expedite the planning for construction of the authorized projects in the southeastern Oklahoma and southwestern Arkansas section.

Upstream flood prevention

In any study of the various aspects of water resources in Oklahoma, attention must be given the upstream flood prevention program. The flood protection to farmland and to cities and towns on the tributary watersheds of the larger rivers, as well as the development in these projects for municipal, agricultural, and recreational purposes are important factors. Interest in the program has developed to the extent that applications are now on file covering 5,095,040 acres of land in the authorized Washita River watershed. Under Public Law 566, applications now are on file for 72 watersheds covering 8,479,616 acres. These projects are in various stages of development, ranging from completed projects to merely applications on file. The importance of this type project, and the attitude of the local people, is demonstrated by the number of applications on file requesting the program. The applications on file represent virtually every area of the State, ranging from the well-watered area of the southeast to the western part of the State where rainfall is light.

The effectiveness of the program has been demonstrated by those projects that have been completed and in operation for a number of years. The overall value of these projects for flood prevention, municipal water, irrigation water, and recreation has not been realized because of the short length of time that has elapsed since completion. It has become apparent that, where sufficient surface water is available, more multiple uses of the water impounded and available for impoundment in the flood prevention structures must be made if the maximum use of the water resources is to be made.

In another section of this report, there is a projection of the population growth and water use in Oklahoma for the years 1975, 2000, and 2025. These figures reflect a tremendous increase in the need for water in the future. It is estimated that applications will be filed at the rate of 10 to 15 per year under Public Law 566, until applications for works of improvement have been filed on the approximately 350 small watersheds that are economically feasible under the present method of justification.

To meet the increase in the need for water, particularly in the smaller cities and towns, and for irrigation, the upstream flood prevention program must be speeded up and encouragement given to the cities and individual farmers to participate in storing water in the flood prevention structures. These uses are in addition to the primary purpose of the upstream flood prevention program-preventing floods on the tributaries of the larger rivers of Oklahoma.

Ground water resources

The rocks and deposits underlying Oklahoma are estimated to contain more than 300 million acre-feet of potable ground water, approximately half of which could be developed. Total replenishment for the State is unknown, in places estimates place it at 20 percent of the precipitation, but if replenishment is only 2 percent of the precipitation, ground-water use could be increased sixfold without depleting the available supply.

In 1956, one-third of the water used in the State, or 400,000 acre-feet, was ground water. Ground water supplies more than 70 percent of the irrigation water supply, more than 50 percent of domestic water, and a large part of the rural domestic and stock water. More than 300 towns and cities of the State obtain all municipal water from underground water sources. The water occurs in a variety of geologic formations; unconsolidated sand and gravel, sandstone, limestone, gypsum, and shale. Wells often yield more than 1,000 gallons per minute, and fresh water occurs to depth of 3,000 feet.

In addition to the fresh ground water, the State has great quantities of mineralized ground water, some of which is at a relatively shallow depth and can be used when economical methods of demineralizing water have been developed.

The ground-water potential of the State has been only partly developed. Locally, this resource is overdeveloped at or near Norman in the central part. In the Norman area, the overdevelopment has resulted from improper well spacing. With proper spacing of wells, the aquifer could sustain several times the present pumping draft. Ground-water development for irrigation in the western two-thirds of Oklahoma is now 95 percent of the potential given in the 1955 interagency report on the Arkansas-White-Red Basins. However, there is no evidence of overdevelopment, and ground-water irrigation probably could be increased

The principal problem affecting ground-water development is the lack of detailed facts concerning its availability and occurrence, source and rate of replenishment, and chemical quality. A systematic inventory of pumpage is needed, as is a program to relate use to change in aquifer storage. All these problems and needs involve complex and time-consuming studies. The effects of planned water developments on ground-water storage and replenishment, the practicality of artificial recharge, and combination projects using ground and surface water should be studied.

Water quality and stream pollution control

At the present time Oklahoma's streams are not loaded with domestic waste. Most cities of any size have some form of sewage treatment, as a matter of fact, Oklahoma, as a State ranks seventh in development of sewage treatment facilities. The main water quality problem in the development of Oklahoma's water resources is mineralization from both natural and manmade sources. Two of the principal streams in Oklahoma carry large concentrations of salt dissolved from natural deposits. These are the Salt Fork of the Arkansas River and the Cimarron River. One of the larger streams in the State affected by oilfield brines is the Canadian River. Under present watershed conditions for the water impounded in the Eufaula would be rather poor quality. The mineralization problem is due to the serious "bog" in technical knowledge as to how to dispose of brine. However, both Oklahoma and Texas are, at this time, vigorously attacking the problem of improving water quality.

As Oklahoma develops, both domestic and industrial waste loads will increase, in fact, it will increase out of proportion to increased water usage. The Oklahoma State Water Resources Board has adopted a water quality criteria establishing "instream" standards in an attempt to protect the streams as the future develops.

The U.S. Public Health Service study of mineralization, including the Red River system to Shreveport and all of the Arkansas from Great Bend, Kans., to Little Rock, Ark., should pinpoint sources of manmade pollution and offer suggestions for the alleviation of the effects of natural pollution. As far as this last point is concerned, the possibility of off-channel storage, diversions to other watersheds, and reinspection appear promising.

It is noteworthy that at the present level of knowledge regarding organic waste disposal, such as sewage, sanitary dilution to prevent further algae pollution is necessary. The amount of sanitary diluting waste required is approximately three to four times that required by the municipality producing the waste. The full impact of this concept is, that without substantial advances in treatment techniques, water available for sanitary dilution may well become Oklahoma's principal growth-controlling factor rather than availability of water per se.

Future water requirements

Future water requirements for the State of Oklahoma have been estimated for years 1975, 2000, and 2025. These requirements were arrived at by reference to performance of well-watered areas with the assumption that if Oklahoma were to receive adequate water it would grow as well-watered areas have grown and continue to grow. Oklahoma's growth through migration and resulting catalytic growths appears to hinge on water resources; consequently, these estimates, or talking figures should be used only as guidelines.

Future water requirements are the product of the estimated future population and the total per capita use of water.

Population estimates for the State of Oklahoma were determined first by projecting the population of the United States, and assuming no migration in or out of the continental area. And secondly, by assuming that some already saturated areas of the United States are unlikely to continue to accommodate continuous rapid increases and that migration is likely to occur to less-populous areas capable of more dense, urbanized development. Oklahoma's share of the national increase was weighted by three factors, designed to reflect growth on the assumption of a major increase in available water resources. These factors are a comparison of urban growth rate, urbanization, and population density in well-watered areas to those of Oklahoma. On the basis of these calculations, the indicated values for the population of Oklahoma were 2,890,000 in 1975; 4,500,000 in 2000; and 5,380,000 in 2025.

The three categories of water use employed by the State of Oklahoma are municipal, direct industrial, and agricultural.

Municipal use includes the water used domestically, industrially, publicly, and commercially. Also included are losses incurred in getting the water to the consumer. At present there are 388 municipalities with individual water supplies in Oklahoma, 76.9 percent of which are groundwater supplies.

Following the basic theme of the population studies, namely: that with adequate water Oklahoma could grow as well-watered areas have grown and continue to grow, the problem then was to make the per capita consumption comparable to those of well-watered areas and, at the same time, to provide for the increased water requirements resulting from the general upgrading of the standard of living.

The per capita values were first estimated for the years 1975, 2000, and 2025; these were: 148, 185, and 235 gallons per capita per day, respectively. The per capita consumption for Oklahoma in 1950 was 81 gallons per capita per day, and 103 gallons per capita per day in 1955.

The total municipal requirements were computed as the product of these values and their corresponding population estimates; the 1975, 2000, and 2025 figures are 0.490, 0.945, and 1.44 million acre-feet per year, respectively.

It is envisioned that industrial development in Oklahoma will acquire a greater percentage of its water from municipal sources than is expected nationally. In other words, these estimates may be low because it is believed that much of the industrial development will be of the type requiring no direct industrial water. Nationally, the direct industrial water requirements is approximately seven times the total municipal requirement. In Oklahoma the direct industrial requirement is predicted to be less than the municipal requirement in 1975 and 1.4 times the municipal requirement in 2025.

In computing the industrial futures, consideration was given to the adoption of conservation practices in new industrial development. Also, it is hoped that industrial development will be programed to prohibit the development of wasteful users and permit the utilization of multiple use of water from industry to industry.

The industrial water requirements were computed to gradually reach what would be considered basically the process water requirement with a modest cooling requirement insisting on full conservation practice, programed use, and reuse as well as industrial development with the exclusion of excessive water consumers. Using the preceding criteria, with full development in year 2025, the future industrial water requirements would be 0.290, 1.3, and 2 million acre-feet per year for years 1975, 2000, and 2025, respectively.

Approximately 300,000 agricultural acres are being irrigated at the present in Oklahoma. Taking such factors as suitability of the land, flooding hazards, and inadequate drainage, it is estimated that 2,012,000 acres are suitable for irrigation.

Applying a consumptive use of 2.3 feet per year (27 inches of water per acre per year), this is envisioning intensive irrigation and using high value crops, and an ultimate of 660,000 acres of land, a future requirement in year 2025 of 1.272 million acre-feet per year is arrived at. Years 2000 and 1975 would have 0.950 and 0.400 million acre-feet per year, respectively.

Total future water requirements

The total water consumption has been doubling every 25 years, or increasing at the rate of 3 to 4 gallons per capita per year. The total future requirements were computed by summarizing the component parts, namely: municipal, agricultural, and direct industrial requirements. They are estimated to be in years 1975, 2000, and 2025, respectively, 1.4, 3.67, and 5.21 million acre-feet per year.

Factors of future importance

The future of Oklahoma will require water in excess of the supply as we now know it. Consequently, attention must be given to practices designed to store water in "wet" years, equalize supply on an areal basis, and conserve what water is available by programed use and reduced losses so as to obtain maximum use of that which is available. This may very well not suffice. The movement of large volumes of water into the semiarid areas or demand areas may also be required.

The conservation practices may be divided into two general categories: (1) Better conservation of what is available, involving regulations of extremes, programed use and reuse, loss reduction, etc.; and (2) transfer of water from overabundant areas to deficient areas. More specifically the following practices are recommended:

1. Complete development of all reservoir sites to iron out the wide fluctuations in surface supply.
2. Integration of the various multiple purposes into all sites, including where feasible, power, flood control, navigation, irrigation, public water supply, and recreation.
3. Integration of the various techniques of upstream retention on a basin basis, including both mutiple-purpose dams and soil conservation projects.
4. Development of techniques of design to upgrade the quality of our mineralized waters, perhaps offchannel storage, brine injection, etc.
5. Development of visionary plans, such as the Central Oklahoma Water Supply and Navigation Canal, to redistribute water from our abundant southeast to our semiarid central and western areas.
6. Insistence on conservation practice in the use of water, particularly that used by industry directly, and investigation into the feasibility of reuse.
7. In the future, water quality will become of increasing importance. In fact, it may actually control, through sanitary dilution requirements, the future water uses. Consequently, research into new methods of waste disposal is essential.
8. To provide administrative, financial, and legal means to completely integrate water developments, such that optimum use of ground water, waste water, and surface water can be planned.

In addition, basic data programs should be accelerated and studies on weather management, watershed management, desaltation processes, and evaporation control continued.

In general, Federal-State relations have been good in Oklahoma and Oklahoma is looking forward to a continuance of their fruitful relationship.

In summarizing it is recognized that a total water program must include integration of all water uses. It will require a coordinated program of State and Federal planning for the ultimate development of surface and ground water resources. An important part of the future program must of necessity begin with research on how to get more yield and better quality water for Oklahoma.

Although navigation is a nonconsumptive use of water, we feel that we should call to the attention of the committee its importance to the overall development of water resources of Oklahoma:

Navigation of the Arkansas and Verdigris

Navigation of the Arkansas and Verdigris River has been authorized by the Congress up to Catoosa, Okla. The Oologah project on the Verdigris River, Keystone on the Arkansas River, and Eufaula project on the Canadian River are basic projects required for successful navigation on the Arkansas River and these projects are now under construction. The economic benefits of these projects cannot be overemphasized. It is hoped that this highly desirable project can move forward at a rate that will see navigation of the Arkansas River within the next decade.

Congress has made available funds for preliminary investigations of the central Oklahoma project, commonly referred to as the HOW project. We sincerely hope the engineering report will show economic feasibility for this project so that water transportation to central Oklahoma can be realized.

Hydroelectric power

The importance of hydroelectric power to the State of Oklahoma for its industrial development is of major importance and in the development of individual multiple-purpose projects throughout the State. The inclusion of hydroelectric power where practical and feasible must not be overlooked.

OREGON

STATE OF OREGON,
COMMITTEE ON NATURAL RESOURCES,
Salem, October 12, 1959.

Hon. ROBERT S. KERR
Senate Office Building, Washington, D.C.

DEAR SENATOR KERR: Pursuant to your request that Governor Hatfield provide you with a statement as to the water problems of the State of Oregon, both present and anticipated to arise between now and 1980, this will advise that the Committee on Natural Resources is presently compiling information for your committee.

We note that you have requested that this information be made available by October 1, and we are writing at this time to indicate it will be forthcoming in the very near future. Obviously, this is a broad and complex subject which demands considerable analysis. Information has been received from the several State agencies concerned and is now being correlated into a statement for the use of your committee.

Yours very truly,

DAN P. ALLEN, *Executive Secretary.*

REPORT OF THE STATE OF OREGON TO U.S. SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES, NOVEMBER 1959

INTRODUCTION

This report has been prepared for the U.S. Senate Select Committee on National Water Resources, pursuant to a request from Hon. Robert S. Kerr, chairman of the committee.

Under the provisions of Senate Resolution 48, adopted April 20, 1959, the select committee is assembling and analyzing all information on the Nation's water problems.

Information included herein has been compiled from material submitted by the Oregon Water Resources Board, Oregon State engineer, Oregon State Game Commission, Oregon State Fish Commission, and the Oregon State Sanitary Authority.

In 1955, the Oregon Legislature created a comprehensive water policy and established the Oregon Water Resources Board to carry out this policy. The board was instructed by the legislature to proceed as rapidly as possible to study existing water resources of the State, means and methods of conserving and augmenting such water resources, and the existing and contemplated needs and uses of water for domestic, municipal, irrigation, power development, industrial, mining, recreation, wildlife, and fish life uses, and for pollution abatement—all of which were declared beneficial uses by the legislature. The board was further instructed to consider all other related water-use subjects, including reclamation and drainage.

It has been generally acknowledged that Oregon's is a model water law, particularly among Western States. For the first time, all beneficial uses of water are given equal status in determining priorities of use, with only human consumption and livestock use as dominant in the event of irreconcilable conflicts.

It is hoped that this report may prove of assistance to the members of the select committee in their important deliberations. Obviously, in many instances, Federal-State cooperation is of vital importance in the solution of water problems, both in Oregon and elsewhere in the United States. It is in such a cooperative spirit that Oregon submits this report.

GENERAL STATEMENT ON WATER SUPPLY

Climate and other factors

Perhaps no region of similar size has so wide a variety of climate as does Oregon. The marine influence on one side and the continental influence on the other results in striking contrast. The mountain barriers running north and south prevent free interchange of air. These barriers also greatly affect the temperature and moisture content of the air masses that surround them.

The variation in precipitation in different parts of the State is quite pronounced. The geographic distribution of precipitation is profoundly affected by topography; the heaviest rains being on the slopes exposed to the ocean.

There are some locations on the west slope of the Coast Range that have heavier precipitation than has been recorded in any other State, while east of the Cascade Mountains there are areas having less than any part of the United States east of the Continental Divide. Only 12 to 20 percent of the State's annual precipitation occurs during May through September. Some areas have a minimum annual precipitation of 50 or more inches, but they receive an average of only one-half inch during July and August.

Surface water

Oregon's rivers carry about 88 million acre-feet of water to the ocean in an average year, and some 49 million acre-feet of water evaporates from the land surface, is transpired by trees and plants, or used consumptively by man.

The Columbia River forms most of Oregon's northern boundary. The average annual discharge of the Columbia River at its mouth is approximately 180 million acre-feet. Oregon's average annual contribution to the Columbia River is approximately 35 million acre-feet of discharge directly into the Columbia River, while some 3,800,000 acre-feet reaches the Columbia River through the Snake River drainage.

Oregon's coastal streams discharge about 48 million acre-feet into the Pacific Ocean annually. The Umpqua and Rogue are Oregon's largest coastal rivers, with average annual discharges of 6,700,000 and 5,660,000 acre-feet, respectively. Most of Oregon's streams are characterized by low discharge during summer months, the period of greatest water need. Low elevation watersheds produce peak discharge during the winter months. High elevation watersheds store winter precipitation through snow accumulation which delays runoff until spring or early summer months. The average annual consumptive use of water in Oregon for irrigated agricultural lands probably exceeds 2 million acre-feet. The amount of water evaporated on bodies of water in an average year has been computed as 2 million acre-feet. Of this amount, about 750,000 acre-feet evaporates from basins that have no outlet to the sea.

Releases of water from storage reservoirs has increased summer stream discharge in many of the State's streams. This stored water is committed to consumptive use except for releases from storage of Corps of Engineers, U.S. Army, reservoirs in the Willamette River Basin.

The total known capacity of Oregon's 1,290 reservoirs is 5,399,820 acre-feet in August 1959. Of this total, 4,615,800 acre-feet is useful or effective storage. Most of the remaining or dead storage is used for recreation, conserving fish life, wildlife, or creating a head for powerplants. Non-Federal (private) interests have constructed 2,414,320 acre-feet or 52 percent of the total known effective storage in Oregon. Federal interests have constructed 2,201,480 acre-feet or 48 percent of our effective storage.

Occurrence of ground water in Oregon

Important ground-water supplies occur in the Willamette Basin, the Cascade Mountains, and several intramountain basins such as Walla Walla, Umatilla, Fort Rock, and Harney Basins. Few basins contain all of the three basic considerations for good ground-water potential, according to the U.S. Geological Survey.

WITHDRAWALS, RESERVATION, AND USE OF WATER

Federal withdrawals

Federal withdrawals and reservations constitute a serious legal problem confronting the State in the planning and administration of its water resources. Recent U.S. Supreme Court decisions have cast a cloud on the validity of water rights acquired under State law in those areas where the water originates from or flows through reserved or withdrawn lands. Fifty-two percent of the land area of the State of Oregon is owned by the Federal Government. The Federal ownership represents the major mountain areas which produce the major quantity of the water resources of the State. A major portion of the Federal ownership is in U.S. Forest Service or other reserved lands. There is an urgent need to clarify the status of Federal-State jurisdiction over water.

State withdrawals

Oregon's State engineers have made withdrawals of water in the amount of 3,649,000 acre-feet and 2,600 cubic feet per second for storage or use, under the authority of chapter 87, Laws of Oregon, dated 1913. Most of the State's large irrigation reservoirs have been built under authority of these withdrawals. The status of some of these withdrawals has not been fully determined.

Oregon's Legislature has made withdrawals on restricted use of water on many streams through the years to protect scenic attractions, recreation areas, and fishery uses.

In 1955 the Oregon Legislature enacted into law a comprehensive State water policy and established the State water resources board to carry out this policy. In progressively formulating this integrated, coordinated program of water use and control, this board is classifying waters for greatest beneficial use; and, when based on need, is establishing base perennial flows which shall be preserved against future appropriation. This is, in effect, making a withdrawal of water.

Rights to use 65,983.89 cubic feet of water per second were issued to water users by the State between 1909 and 1953. Of this total, 35,134.46 cubic feet per second were for power uses. The State had issued rights to irrigate 2,663,910 acres of land by 1953.

Surface water appropriations for consumptive use increased about 7,300 cubic feet per second from 1945 through 1957.

FUNDAMENTAL SURFACE WATER PROBLEMS

Oregon's seasonal maldistribution of precipitation and resultant stream discharge often creates damaging floods, followed by critical water shortages during the summer months.

The Corps of Engineers, U.S. Army, estimates the average annual flood damage at $19,552,400 in areas they have studied in Oregon, based on 1952 to 1954 price levels and 1939 to 1952 developmental levels. Estimated average annual flood damages in the Wallowa, Goose Lake, Klamath, most of the Deschutes, and many coastal basins is not available.

Most Oregon streams have a critical period during the late summer when the flow available at that time is not sufficient to meet the present demand. In some streams in eastern Oregon the water demand, over the entire water period, is quantitatively in excess of the yield that can be normally expected.

This seasonal maldistribution of water creates hardships for all water uses. Mining is usually restricted to winter operations. Irrigators with late priority water rights attempt to store maximum amounts of water in the soil early in the growing season. This often results in the leaching of plant nutrients. Municipal uses are sometimes curtailed. The State's fishery resource is difficult to maintain and sometimes impossible to improve when floods scour spawning beds and low flows restrict habitat and create critical temperatures. Water quality, particularly temperature, is becoming an increasing problem in the State. Temperatures on major streams have been recorded higher than those compatible for habitat or passageway for food or game fish.

Conflicts arise between water users for the right to use the remaining unappropriated waters. Fishery interests want continuous streamflows unimpeded by dams that will block spawning areas for anadromous fish. Consumptive users of water wish to take water from the streams, particularly during hot, dry summers when streams have their lowest discharge. Recreation interests want full reservoirs during the summer, at the same time when irrigationists must effect drawdowns.

FUNDAMENTAL GROUND WATER PROBLEMS

A deficiency in basic data is Oregon's primary ground water problem. Determining safe and economical yields of ground water is impossible without additional research in most of Oregon. Areas where economical artificial recharge may be effected are largely unknown.

Ground water supplies have been inadequate to satisfy present ground water uses in the Milton-Freewater area, the Dalles area, and part of the Willamette Basin.

Salt water is occasionally found in marine sedimentary rocks beneath the Willamette Valley, the Coast Range, and the Klamath Mountains. Highly mineralized water is often found along fault lines in the southeastern plateau.

Few basins contain all of the three basic considerations for good ground water potential, according to the U.S. Geological Survey.

Division	Precipitation	Porous rocks	Gentle topography
Southeastern plateaus	Poor	Good	Fair.
Columbia plateau slope	Fair	Fair	Fair to poor.
Central and central-eastern mountains.	do	do	Poor to fair.
Cascade Range	Good	Good to fair.	Poor.
Klamath Mountains	do	Poor	Do.
Willamette Valley	do	Good to poor.	Good.
Coast Range	do	Poor	Poor.
Coastal belt	do	Poor to fair	Fair.

ANALYSIS OF PRESENT AND PROBABLE FUTURE PROBLEMS

Population projections

The growth of Oregon's population is shown in the following table:

Oregon population

Census date	Population	Increase over preceding census	
		Number	Percent
1850 (June 1)	12,093		
1860 (June 1)	52,465	40,372	333.8
1870 (June 1)	90,923	38,458	73.3
1880 (June 1)	174,768	83,845	92.2
1890 (June 1)	317,704	142,936	81.8
1900 (June 1)	413,536	95,832	30.2
1910 (Apr. 15)	672,765	259,229	62.7
1920 (June 1)	783,389	110,624	16.4
1930 (Apr. 1)	953,786	170,397	21.8
1940 (Apr. 1)	1,089,684	135,898	14.2
1950 (Apr. 1)	1,521,341	431,657	39.6

Source: U.S. Department of Commerce and Oregon State Board of Health.

Estimated present and future population is as follows:

Census date:	*Population*
1958 (July 1)	1,728,550
1970	2,132,363

Source: U.S. Department of Commerce and Oregon State Board of Health.

It is assumed that this population increase will be distributed geographically about as it is now with the major increases occurring in the Willamette Valley, southern Oregon, and along the Columbia River.

Municipal water use

Oregon's incorporated city water systems used an estimated 65,909 million gallons of water during fiscal year 1951-52. These cities served approximately 1,300,000 persons or 86 percent of Oregon's population. It was estimated that 8,488 million gallons were used during the maximum demand month. Suburban living has increased the per capita water requirements. Residents of Oregon's 11 largest cities used nearly 340 gallons per capita daily during the maximum demand month. Acute water shortages have been reported in cities near Portland as well as other Williamette Valley towns and cities.

Water needs of industries

Processing forest and agricultural products constitutes Oregon's largest industrial uses of water. Other uses include cooling, other processing, fire protection, and storage (log ponds). In 1954, the Bureau of Census reported that Oregon had 37 pulp or paper plants and 198 plants manufacturing food and kindred products, all with 20 or more employees. By 1957, $72,891,227 was paid for covered employment in food and kindred products industries and $337,618,583 was paid for covered employment in lumber and wood products industries.

Oregon ranks first among the States in timber production but only seventh in pulp and paper production. Oregon's economy could be broadened and her seasonal employment stabilized by greater utilization of the estimated 40 percent timber waste.

Agriculture use of water

Irrigation is the largest consumptive use of water in Oregon. According to the U.S. census of agriculture, the increase in irrigated acres has been as follows:

1940	1,050,000
1944	1,129,059
1949	1,306,810
1954	1,490,366

By 1954 nearly 2,690,000 acres of land in Oregon held irrigation rights. Rights initiated between 1909 and 1954 total 30,930 cubic feet per second to irrigate 1,475,355 acres. Much of Oregon's farmlands receive enough precipitation to grow crops with small summer water requirements, such as cereal grains. For this reason there is little relationship between the acreage of lands holding water rights and land actually irrigated.

The water resources committee of the School of Agriculture at Oregon State College estimated in 1954 that during the next 25 to 50 years, an additional 1,364,000 acres of land will be irrigated in Oregon. This will require in excess of 3,500,000 additional acre-feet of water. Supplemental water is needed to stabilize production on over 1 million acres presently irrigated in the State.

Flood control

Floods are and will continue to be a serious problem in Oregon. Since the beginning of civilization, people have encroached upon the flood plains because of the availability of water, fertile soils, and other conveniences. Transportation arteries follow our narrow valleys adding to the value of development in the flood plain.

An implemented flood control construction program is needed to maintain our present situation in view of the expected development in flood problem areas.

Electrical energy

More than 98 percent of the kilowatt-hours of electricity produced in the Pacific Northwest in 1950 was developed from falling water. Hydro provided about 30 percent of the total energy for the region, far above the national average. Oregon must rely on hydropower due to the shortage of fossil fuels in the State.

At the end of 1957, Oregon's consumers were served by the following types of electric utilities:

Type of utility	Number of utilities	Percent of customers in State
Privately owned	5	84
Municipally owned	10	7
Cooperatives	18	6
People's utility districts	4	3

Average consumption for residential and rural customers for Oregon operations of privately owned utilities, as well as the total United States, in kilowatt hours, is as follows:

	1957	1956	1955
Oregon	8,139	7,792	7,324
Total United States	3,174	2,969	2,751

If the present per capita consumption rate of increase continues, Oregon's residents will use an additional 5,304 kilowatt-hours or 13,443 kilowatt-hours by 1970. The Oregon State Board of Census population estimate for 1970 is 2,132,363 for Oregon. Using these estimates and trends, Oregon electric consumers will use approximately 28,665,355,809 kilowatt-hours by 1970.

The average annual generation of Oregon's hydroelectric projects by January 1, 1953, was 6,055,880,000 according to the Federal Power Commission. Bonneville Dam generation was included in this total (4,400 million kilowatt-hours). Installed capacity was listed at 820,349 kilowatts.

By August 1959, there was 998,030 kilowatts installed capacity in electric powerplants of over 1,000 kilowatts within Oregon. Of this total, 254,500 kilowatts was Federal and 743,530 was nonfederally constructed. In addition there was 2,626,200[1] kilowatts installed capacity (nameplate rating) on Oregon's border streams, the Columbia and Snake Rivers. Of this total, 398,800 kilowatts was non-Federal generation and 2,227,400 kilowatts was Federal.

Oregon has an undeveloped hydroelectric capacity of about 5 million kilowatts. Most of this potential power will be developed only when fish passage facilities problems are solved and the demand for power economically justifies construction of these projects.

Navigation

Navigation is not a prime factor as far as quantitative use of water is concerned in Oregon. The release of multiple purpose storage during low-flow periods has aided navigation in the Columbia and Willamette Rivers.

Early completion of the John Day Dam and Reservoir and the 27-foot deep and 300-foot wide channel to The Dalles will be of great benefit to Columbia River navigation. The need for this work is evidenced by the fact that 1,750,520 tons of cargo passed Bonneville locks during 1958. New tonnage records were set in 1958 at both Bonneville locks and the Dalles Dam.

Pollution abatement

The Oregon State Water Resources Board has not assigned water for pollution abatement without proper treatment facilities sufficient to insure that the quality of the water will not be lowered.

In 1939, only 93,000 Oregonians were living in dwellings being served by sewage treatment plants. At the end of 1958 there were 168 public and semipublic sewage treatment plants in operation serving an estimated 810,000 persons or 90 percent of the total served population of the State. At the same time, there were more than 100 communities in Oregon that needed new or improved sewage collection and disposal facilities, according to the Oregon State Sanitary Authority. Construction of these needed projects will cost from $30 to $50 million. By the end of 1958, $1,956,000 had been granted to assist 23 Oregon communities, under the Federal program authorized in Congress in 1956. In 1958, the Oregon Sanitary Authority received three times as many applications for Federal grants as there were funds available.

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[1] The Dalles Dam installed capacity was 729,000 kilowatts. An additional generator of 78,000 kilowatts is scheduled to be brought on the line every 3 months to a maximum installed capacity of 1,119,000 kilowatts.

The pulp and paper plants expected to locate in Oregon, pose a problem of locating water for processing and diluting the effluent.

Flows in most streams west of the Cascade Mountains are insufficient during the summer months to assimilate residual pollution loads.

Bacterial pollution and industrial waste discharges have prevented the use of portions of some streams for recreational purposes.

Oxygen conditions in lower Portland Harbor are not always high enough to support runs of salmonoid fish in the late summer and early fall.

The addition of domestic sewage effluents and industrial wastes to streams has impaired their usefulness as sources of domestic, industrial, and agricultural water supplies.

Logging operations and road construction on various basin watersheds cause serious problems of color and turbidity in streams. These interfere with use of waters for recreation, for water supply, and for fish propagation.

Increased population and industrial expansion and development cause pollution loads on streams to increase faster than remedial works have been constructed for correction.

Increased industrial production will create problems of pollution control in certain areas.

Domestic sewage effluent loadings on streams will increase about 50 percent. Extremely high degrees of sewage treatment will be required on both tributary streams and main water courses.

Recreational pressure on all surface waters can be expected to increase proportionally to population increases. This will require that:

1. Water quality be restored and maintained at a high level to protect the public health.
2. Streamflows must be adequate to protect aquatic life and permit water-associated recreation activities.

More industries and more people will use more water and streamflows must be maintained to meet these demands.

Nonbiological contaminants must be controlled to provide safe water for drinking purposes.

Continuation and acceleration of the present joint Federal-community program of State-approved sewage treatment works construction is vital in order to bring about higher degrees of sewage and industrial waste treatment; and additional upstream impoundments having sufficient storage to sustain required flows in all major waterways should be considered.

FISH AND WILDLIFE

The total average annual commercial catch of anadromous and fresh water fish in Oregon is worth about $13,600,000. In addition, about one in every four Oregon adults purchases a sports fishing license. In 1957, 529,061 sports fishing licenses were issued in the State. The average annual expenditure for sports fishing in Oregon has been estimated at a minimum of $100 million. In 1957, 798,805 licenses were issued in the State for hunting. The total deer kill was reported to be 115,364 and the reported elk kill was 5,761. More than 890,500 ducks and geese were taken by over 67,900 waterfowl hunters during the 1958 season.

In considering how to provide hunting and fishing for the expanded population by 1970 and with the other increased pressures for use of water, the following information is pertinent:

Fish management problems

1. *Base streamflows.*—One of the problems upon which attention has become focused in the last 10 years and which will continue to become more acute is the maintenance of adequate streamflows through the natural low water seasons.

One common misconception concerning the establishment of minimum streamflow figures is that the aquatic environment can be maintained if the flow is leveled off at that quantity throughout the year. Minimum streamflow figures are the smallest volumes that can be tolerated in the natural low flow season. The biology of anadromous fish is geared to the natural variation of streamflows at different seasons of the year. A minimum flow that would be satisfactory through the late summer months might be completely inadequate throughout the winter and spring months.

Some scarcities could be overcome if a method of control was established which would insure the proper use of all diverted water and permit none to be wasted. Elsewhere headwater storage of the seasonal surplus could be developed to augment the low flow as well as provide additional water for other beneficial uses.

2. *Water temperatures.*—High summer water temperature is a companion problem to inadequate waterflow. In some areas it has become a serious threat to the management of the native cold water species.

Perhaps some of the high temperature problems can be remedied through the storage of the seasonal surplus for release during the critical periods. Before any such project is initiated, it must be predetermined that the stored water will be in adequate supply and of proper quality. Releases of water of undesirable quality could be disastrous. Thorough studies of the probable effects of supplemental releases should be made in conjunction with the other planning if the developments are to enhance the fishery resource rather than destroy it.

3. *Passage facilities at barriers.*—Much thought and effort is being given to the problems surrounding passage of young and adult migratory fish at manmade barriers. Substantial successes have been achieved at many dams as well as at natural waterfalls, but as basin development projects become more complex, greater fish passage problems are created. All of the public fishery management agencies, as well as some of the construction agencies, are giving their combined talents to the search for adequate solutions to the passage problems. Given sufficient time and resources, there is reason to believe they will be successful.

4. *Protection at diversions.*—Closely associated with the problem of safely passing young anadromous fish downstream around barriers is the matter of protecting them from diversions for industrial and agricultural uses. Frequently most, if not all, of the natural streamflow is diverted for such purposes. When the amount of diverted water is small, relatively simple screens can be installed to protect the fish. When vast quantities are removed from the river or passed through hydroturbines, the solution becomes difficult.

Small rotary screens have been very successful in keeping fish out of the small irrigation ditches. Most of the diversions that can be protected in that manner have facilities installed, but new ditches are being constructed constantly. Large mechanical screens have been placed in some of the major diversions and negotiations are underway with owners of others for similar installations. A rather recently developed stationary louver-type screen appears to have considerable promise for fish protection in certain types of large ditches. One installation has been completed and efficiency testing is underway.

5. *Pollution abatement.*—Water pollution has become a serious fishery management problem in some streams. The most infamous example is the Willamette River. Industrial and municipal pollution has completely eliminated some races of fish from the basin.

Much progress in abatement of existing pollution has been made, but population growths and industrial developments have created new problems faster than the old ones can be eliminated. Continued growth of the region will require ever-increasing efforts to control the problems.

6. *Trash fish control.*—The construction of basin development projects frequently has changed the habitat so that indigenous species of coarse fish become a nuisance. Populations of squawfish and suckers have mushroomed in the flood-control reservoirs of the Willamette Valley and irrigation impoundments of eastern Oregon to the extent that salmonoids cannot compete for food or living space.

The only effective means known to control the problem is to chemically treat the water to remove all fish life, and then restock with desirable species. That usually is a costly endeavor and unless the watershed above the impoundment can be treated effectively, is only a temporary measure.

7. *Streambed gravel removal.*—The indiscriminate removal of gravel from streambeds has at times caused localized fishery management problems. Sometimes the removal is made while eggs or fry are in the gravel, consequently that part of the production is destroyed.

The natural productivity of some streams has been reduced by gravel removal. A shortage of suitable spawning areas is sometimes a factor limiting fish production. When shortages exist, the removal of gravel further reduces the production potential of the area.

Game management problems

1. *Water distribution.*—The distribution of adequate water supplies has an effect on the distribution of game animals and birds in the more arid parts of the State. Under normal conditions sufficient water occurs throughout most of Oregon to provide for the species occurring in the various areas, but in adverse years some acute shortages are experienced.

Under some agricultural practices water supplies are either eliminated or their use withheld from game species. As the human population grows, greater conflicts will develop resulting in greater restrictions.

Planning to accomplish the utilization of surplus and waste water from some of the reclamation projects for game and waterfowl enhancement would be very beneficial in several areas. Rather than wasting the excess back to the stream, which frequently creates fishery problems, it could be picked up and transmitted to suitable areas for game use or wet land development.

2. *Protection along diversion canals.*—With the increased development of hydroelectric and reclamation water supplies in the back country, big game populations are exposed to new hazards. Open canals, winding for many miles through the mountains, make effective barriers across deer and elk migration routes.

Waterfowl and fur bearer management problems

1. *Marsh and pond drainage.*—The most serious limiting factor affecting waterfowl has been the indiscriminate destruction of wetland areas. It is fundamental that waterfowl need water, and their numbers decline as their habitat is reduced.

Reclamation of many marshlands for agricultural development has proved to be ill advised as the resulting lands were not desirable for farming purposes. Most careful consideration should be given to all factors before further drainage is accomplished, and the rewatering of some areas might be desirable.

2. *Providing adequate water supplies.*—Diversion of water supplies and drainage at adjacent areas have seriously reduced the available water at some of the existing marshes and other waterfowl areas. Management agencies have alleviated some of the distress of acquiring water rights to restore the potential, but the problem remains serious in several areas.

It behooves all public water planning and control agencies to give careful consideration to the needs of waterfowl and fur bearers, as well as all other wildlife, when studying or authorizing future developments.

3. *Stream channelization and cover removal.*—A number of small, localized flood control or drainage projects have been accomplished by removing the bank cover and rechanneling the stream. Most of these waterways, especially those on the floor of the Willamette Valley, provide excellent habitat for ducks, beavers, and muskrats. Frequently the surplus water problems could have been solved by removal of the accumulated drift and debris from the natural stream channel and widening it only at the constricted points.

The importance of water as a recreational feature in Oregon State parks

The use of water for outdoor recreation is becoming of increasing importance in nationwide leisure time activities. Pleasure boating, swimming, fishing, water skiing, and skin diving are the main uses, most of which have shown large participation increases within the last 10 years. According to the Outboard Boating Club of America, pleasure boating is now termed the Nation's No. 1 family outdoor sport, with 37 million persons participating in 1958 and spending $2 billion; 7,330,000 boats were in use as compared to 2,440,000 in 1947. Among other factors, the mobility of pleasure craft and increase in the number of water impoundments throughout the country are contributing factors to greater use. Published reports indicate last year 5 million skindivers spent $30 million on equipment, representing perhaps a 1,000 percent increase in use over 10 years ago. Water skiing, almost unknown a decade ago, has grown along with the boating trend. Such established water use activities as angling and swimming are also increasing.

On the State level, the public's preferences in recreation are reflected in the establishment and development of Oregon State parks. These trends are considered in the selection and planning of State parks, and the use made of the park areas is the measure of their public worth. For example, 19 new State parks have been acquired since 1954 and 17 of these have water interest as their main feature. During the same period the parks division developed another seven areas already in the park system, all of which featured lakes, streams, rivers, or ocean frontage.

State park attendance figures are ample evidence of public interest and use, as illustrated by several of the following examples: Rooster Rock State Park, developed in 1956 featuring boating and swimming, had a 1958 attendance of 417,681; Hat Rock State Park developed in 1955 for swimming had a 1958 attendance of 124,599; Detroit Lake improved in the same year for boating and camping had 148,425; and Ochoco Lake developed in much the same manner had 116,226.

In summary it may be noted that of Oregon's 170 State parks, 90 have some form of water interest for the basis of their attraction. Inasmuch as predictions based on past and present use indicate a substantial increase by 1968, and parks featuring water associated activities and attractions account for approximately 82 percent of total park usage, it is evident that water will continue to play a very important role in providing recreation opportunities for many years to come.

TRENDS IN THE CONSUMPTIVE USE OF WATER FOR WASTE DISPOSAL

Consumptive use of water for waste disposal may be expected to increase with the proposed construction of evaporation lagoons by both industry and municipalities. If Oregon makes full use of her timber resources by utilizing waste forest products and tree thinning, the increase in use of water for disposal of effluent may increase manyfold by 1970. The availability of water and markets will determine the rate of increase.

SOME MEANS OF MEETING FUTURE DEMANDS (NEW TECHNIQUES)

A. Conventional methods of adding new supplies and costs thereof

Programs designed to facilitate reservoir construction of all sizes must be implemented. Reregulating reservoirs have recently proven their value in reducing operational wastes.

Storage projects proposed by Federal construction agencies are available through these agencies. Cost estimates per acre-foot of proposed storage varies from about $20 per acre-foot (Silvies River and Duncan Ferry projects) to well over $200 per acre-foot (Thorn Hollow Dam). As development continues within our proposed reservoir sites, we can expect greater cost of storage in the future as a result of expensive relocations and land acquisition. Ground water studies may discover new water sources and areas where economical recharge is feasible. The practice of range pitting, spreader ditches, and other means of recharging ground water is expected to increase.

B. Vegetative management (reduction of evapotranspiration)

Research is needed in vegetative manipulation on watersheds. Strip or patch cutting practices show promise as a tool in water management in high elevation watershed.

Practically all of Oregon's greatest water-producing areas are forested. More than 30,260,000 of the State's 61,641,000 acres or 49 percent is forested. About 25,875,000 acres or 42 percent of the State's area is in commercial timber production and 4,396,000 or 7 percent is forested with noncommercial timber or the land use is restricted by parks, etc.

Additional research is needed to determine the amount of water consumed by "weed" trees and other woody plants and their effect on the watershed. When adequate basic watershed information is acquired, Federal agencies that now administer over one-half of Oregon should be given funds and authority to implement justified watershed programs. Continued development and use of safe, efficient, and economical chemicals for weed and moss control in and along irrigation canals should be encouraged.

C. Weather modification (induced precipitation)

Additional research is needed for weather modification to induce precipitation or reduce storm damage.

Regional policies should be developed and promulgated regarding the right and extent to induce precipitation if results of research in this field are productive.

D. Evaporation reduction and seepage control

Continued research is needed to provide economical reduction of evaporation on Oregon's 1,290 reservoirs. The use of products presently developed have been restricted due to their cost and a lack of knowledge of their capabilities.

Seepage control has not been a serious factor in Oregon storage projects except in the upper Deschutes Basin. Tumalo Reservoir failed to hold water and the seepage loss at Crane Prairie Reservoir, when full, is estimated to be about 270 cubic feet per second. The development of economical means of reducing or eliminating these losses would be highly desirable.

Transmission and distribution losses constitute a serious loss of water. Present canal-sealing techniques are effective but too expensive in areas where low-income-per-acre crops are grown.

E. Desalinization

The desalinization of ocean or brackish water has not been seriously considered in Oregon. Other sources of water appear to be less expensive and more favorably located for use.

F. New techniques in multiple river management

In 1955, the Oregon Legislature created a comprehensive water policy and created the State water resources board to carry out this policy. The board was instructed by the legislature to proceed as rapidly as possible to study existing water resources of this State; means and methods of conserving and augmenting such water resources; existing and contemplated needs and uses of water for domestic, municipal, irrigation, power development, industrial, mining, recreation, wildlife and fish life uses, and for pollution abatement, all of which are declared to be beneficial uses; and all other related subjects including reclamation and drainage.

After making river basin studies, the board progressively formulates an integrated, coordinated program for the use and control of the water resources and prepares reports and programs thereof.

By 1959 the board has investigated the Rogue, Umpqua, Grand Ronde, and upper McKenzie Basins. The Deschutes, upper Willamette, John Day, and North Coast Basins are scheduled for study within the next 2 years.

G. Effects of nuclear energy

Nuclear energy production presents new problems to water users. The effect and extent of water contamination from radioactive waste disposal and the effect on water temperatures after the water is sued for cooling processes, needs careful study.

H. New technical methods of improving water supply methods

Research is needed for the following:

1. Determining the proper duty of water for agriculture, both in quantity and during critical periods.
2. Reclaiming water from industry, particularly food and wood fiber processing plants.
3. Locating and developing underground storage of water.
4. Long-range weather and streamflow forecasting.
5. Controlling or eradicating undesirable vegetation.
6. Developing food and fiber plants that use water more efficiently.

A program of continued research and the development of basic data that will provide an inventory of knowledge and efficient techniques for utilizing our valuable water resources is of paramount importance.

Multiple-use water resource planning must be continued at an implemented rate to facilitate the productive harvest of Oregon's water crop.

PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA,
GOVERNOR'S OFFICE,
Harrisburg, July 14, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: This will acknowledge receipt of your recent letter which requested a statement regarding present and anticipated water problems of the Commonwealth of Pennsylvania to the year 1980 and our views as to possible solutions to these problems.

We will be most happy to submit the requested statement to the Senate Select Committee on National Water Resources on or before October 1, 1959, and will look forward to the recommendations of the committee when your study is completed.

With kindest regards, I am
Sincerely yours,

DAVID L. LAWRENCE.

SUMMARY STATEMENT OF PRESENT AND ANTICIPATED WATER PROBLEMS OF THE COMMONWEALTH OF PENNSYLVANIA FOR THE SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES

The administration of the many and varied branches of Pennsylvania's water program is vested in several different agencies. Accordingly, this statement represents a summary of the thoughts and opinions expressed by the several agencies concerning the present and anticipated water problems facing the Commonwealth.

The coordinating agency has made no attempt to list the problems in order of magnitude, gravity, or importance. They are all considered serious and all are important; each has its own place in the overall picture.

Pennsylvania is well endowed by nature with water resources. The average annual precipitation over the Commonwealth is approximately 42 inches, which exceeds the national average by about 40 percent. Slightly less than half of this precipitation, about 20 inches or 40 billion gallons per day, finds its way into our streams as runoff. In 1951, a comprehensive inventory of water use in Pennsylvania indicated that an average of 11 billion gallons per day, including reused water, was withdrawn to meet all demands. Only 5 percent of this water was obtained from ground-water sources. Pennsylvania has more rivers and streams than any State in the Union. Her 4,400 streams of various sizes are located in five major drainage basins: the St. Lawrence, the Delaware, the Susquehanna, the Potomac, and the Ohio.

An abundant water supply coupled with a mountainous terrain has made Pennsylvania a flood-conscious State. Accordingly, the Commonwealth has in the past followed the path of doing first things first, dealing with water problems as they presented themselves and the need appeared. While this has made the State a leader in the fields of flood control and pollution abatement, it is now becoming evident that this course will no longer suffice. We must now begin to anticipate water problems before they appear or become too serious.

While, as mentioned above, Pennsylvania has an abundant supply of water, this fact alone will not, as in the past, assure adequate future supplies of good water for all uses and to meet all demands. The very complexity of modern-day living with its attendant varied demand on our water supply has been the contributing factor; good water is even now not always available in sufficient quantity and of the desired quality at the time and place it is required for use.

Industry and urban development are on the move and in search of good water as a prerequisite of plant relocation for industrial expansion, and for municipal use. The use of good water unfortunately results in the production of waste water. While we attempt to control this problem through our clean streams activities, the day of strict allocation for uses that will best serve the public interests seems to grow closer each year; and such control seems to be essential if we are to adequately conserve our water resources.

Due to the rapid development of our chemical industry and other industries involving chemical processes, there has been an increase in the complexities of wastes discharged to our streams. This is in addition to the increased use of detergents, chemicals, insecticides, pesticides, radioactive substances, etc. Many of these materials are either difficult to treat or the effect of treatment processes upon them is not well known. Our ability to detect complex organics in the stream is extremely limited. Many of these materials ultimately find their way back into our public water supplies and are consumed by our population. It is impossible for us to tell at this time whether or not the consumption of these materials has any adverse effects upon our population in relation to chronic diseases such as cancer, etc. We know that some of these materials adversely affect fish life. It is essential that Federal research efforts in this area be doubled or tripled in an attempt to obtain the answers to these questions.

Thermal pollution from industrial sources, especially power and steel production, is presenting increasing problems to the recreational uses of our waters not only from the standpoint of fish production but also because it affects the adequacy of cool water needed for domestic and industrial purposes. Increased temperature also reduces the self-purification capacity of the stream.

Although we are in the process of providing treatment of sewage and industrial wastes prior to their discharge into our waters, there is, at this time, an economic and technical limit to the removal of pollutional qualities from water. Once this limit is reached, increases in population and industrial expansion add pollution and deteriorate our water resources. It is at this point that low-flow augmentation becomes essential for the needed improvement in water quality.

We have already testified before the Senate Subcommittee on Rivers and Harbors concerning our support of H.R. 3610, which proposes to double Federal grants available to municipalities for sewage treatment works. We have found that such assistance has resulted in an increase in sewage treatment plant construction and feel that such increased assistance is essential now for the program to go forward successfully.

Fallout from the testing of nuclear bombs and discharges from nuclear reactors and other sources of radiation have raised the general level of radioactivity in our streams. Presently, most of this is due to the effects of fallout. Nevertheless, our population is consuming water of a higher radioactive content than it was 10 years ago. Serious questions as to the genetic effects due to this increased use of radioactivity have been raised. Much more study needs to be given to this question in order to determine whether or not this is a serious problem and whether the growth of nuclear power which will invariably result in more radioactivity in our streams will indeed mean progress to our civilization.

The problem of the burial or storage of solid radioactive wastes has by no means been solved. If improperly handled, it may result in radioactive pollution of our ground waters.

One of the most serious problems we face in Pennsylvania is the fact that some 2,000 miles of our streams are polluted with acid mine drainage emanating from both subsurface and surface (strip mining) operations. The sanitary water board has carried out a successful program in preventing further deterioration of streams by mine drainage, but the problem of discharges from active and abandoned mines located along already acid streams has certainly not been solved. In order to attempt to solve the problem, we need to determine: (1) Additional means for eliminating or minimizing acid mine drainage from mine operations through a practical research project; (2) some means for control at the source of acid mine drainage from abandoned or inactive operations; (3) reasonable and practical methods, through further research, for reduction of the amounts of water entering the mines and for the treatment of acid mine drainage to remove its pollutional properties; and (4) on watersheds where acid mine drainage cannot be eliminated or adequately reduced at the source. study is needed to determine the practicability of and the advantage to be gained by (*a*) the impoundment of such drainage during peaks of high acid flow with subsequent regulated release of the acid waters so that downstream adverse effects will be eliminated, or (*b*) the impoundment of clean waters in dams on clean streams, tributary to acid polluted streams, and the release of such waters to augment the flow and neutralize the effects of the acid mine drainage in the receiving stream. There have been virtually no Federal efforts toward the solution of this water resources problem. An additional problem in pollution is posed by the erosion of culm piles and mine banks which creates massive downstream sedimentation problems.

It has become increasingly evident in recent years that pollution of our ground water supply is becoming a major problem. In many regions of the State, underground water is now unusable, or is in danger of becoming so. Because Pennsylvania has an abundant rainfall and the greater share of our supply is drawn from surface streams, we are not, at this time, faced with any regional declines of water level. We are, however, confronted with depletion of underground supplies through pollution, and, in some local areas, through overpumping for agricultural, industrial, and municipal uses.

Bacterial pollution is becoming a serious problem in suburban areas where many real estate developments have sprung up using closely spaced wells and septic tanks. In some of these areas water moves largely or entirely, through cracks, fissures, and solution openings in the rock. The problem is intensified in limestone areas by the fact that the soil developed over limestone often has poor drainage characteristics and the standard septic tank does not operate well. Disposal into drilled wells (cesspools) is therefore commonly resorted to. This has led to pollution of large bodies of underground water in some areas. It is exceedingly difficult to trace the course of movement of water through the openings in the rock. The source of pollution cannot always be determined; and further, if determined, it is difficult if not impossible in our present state of knowledge to predict the future spread of the pollution.

Chemical pollution is of many types, and since it can spread through all types of aquifers, it is a more widespread problem than bacterial pollution. Acid mine water, salt water, both sea water and natural brines, industrial wastes, and runoff from "sanitary landfill" are all sources of existing chemical pollution. We are now just beginning to cope with the problems of preventing pollution by nuclear wastes. Specifically, the problems are to locate and track movement of the pollution, determine trends of increasing pollution or dilution, determine the effects of the reaction of aquifer minerals with pollutant, etc. These problems certainly need more research and study.

Pennsylvania's public water supplies for domestic and municipal use are given the highest type of priority. Shortages, however, can and do occur, particularly during drought periods. During 1957, for example, 34 public water supplies experienced serious shortages. A considerable number of public water supplies are using inadequate sources of supply and/or antiquated treatment facilities. While they do produce a safe water, financing for improvements is often lacking.

Surburban development is increasing rapidly. Public water supply and sewerage systems have not been able to keep pace with this expansion. The result has been an increase in individual wells and subsurface sewage disposal systems, with their attendant health hazards and nuisances. If public water supplies are to serve the growing population of Pennsylvania with ample amounts of safe water, it is becoming evident that local funds for advance planning, development of supply sources, and expansion of distribution systems will have to be supplemented. In many cases, municipalities can no longer bear the entire financial load necessary to the development of adequate supplies. Provision for municipal water in Federal and State storage projects is becoming increasingly urgent and it appears that assistance in distribution of water from these sources may be required in some instances. In most cases, however, provision for low-flow augmentation from storage sources in times of water deficiency would serve this purpose. More water impoundment for multiple uses in Pennsylvania than is now in existence or in prospect is urgently needed for a wide variety of purposes. In addition to major basin projects, provision should be made in small watershed programs (Public Law 566) for storage for low-flow augmentation. Additional studies leading to combined Federal-State-local action programs similar to that being conducted in the Delaware basin, and completed in the Brandywine Creek basin in Pennsylvania, are needed on all sizable watersheds of the State.

Availability of ground water supply in the Commonwealth is controlled primarily by the effect of local geology and well yield. The principal problem here, then, is in finding rocks which will yield water at the required rate. The rate of yield is controlled chiefly by the geological characteristics of the aquifer. In terms of providing supply, the problem is to evaluate, in advance, the probable yield of aquifers in an area to be developed. The problems of determining when the limits of ground water withdrawal are being reached, and the allocation of rights if control of withdrawals should be attempted, are coming to the fore. More knowledge and studies on our underground waters are urgently required before these questions can be adequately met. In addition, more research is required to determine under what conditions treated wastes can be discharged to our ground waters without harm, and to determine the possibilities of recharging ground water in areas where there has been a serious depletion.

As stated before, Pennsylvania is a flood-conscious State, and, as a result, her flood control, stream clearance, and encroachment control programs are among the best in the country. Notwithstanding this fact, it is quite evident that we are barely holding our own, since much of our past work has, of necessity, been of a temporary nature. Runoff from rainfall is extremely rapid in Pennsylvania due to her terrain, and there is not a single area within the State which is not flood prone.

Changes in topography to meet the needs of our rapidly growing population, such as, the construction of highways and airfields, the clearing of wooded and agricultural areas for residential and industrial purposes, have contributed to the increase of runoff rates, and the consequent increase in flood potential. Utilities, communications facilities, highways, and industrial and urban growth have always followed our river valleys, and have encroached upon our flood plains. Here again, due to our mountainous and hilly terrain, it is unlikely that this pattern can be changed. This fact, coupled with the delays attendant to the construction of flood control projects, and the lack of adequate financing to do much more than the necessary minimum, has made our flood control problem a continuing one. It is generally recognized that many local communities cannot afford to take the necessary steps for their own protection. The Commonwealth's program at the present time is designed to fill the gap between the protection provided by Federal projects and that provided by the local people themselves.

Lack of adequate storage sites, if not reserved for future use, will become a major problem shortly.

Agricultural areas are frequently subjected to floods in "upstream" areas. These floods cause damage to soils, crops, buildings, and other agricultural resources as well as roads, bridges, and communities. They are usually lower frequency floods, but there are so many of them that they account for a high percentage of total flood damage. Pennsylvania's response to the upstream watershed conservation and flood prevention program under Public Law 566 is an indication of the extent of this type of problem. In 5 years, over 40 applications have been received. This program should be encouraged through higher appropriations for planning and construction.

Federal and State cooperation has been excellent in the past, but it is quite obvious that expanded programs at both levels will be essential in the future. Revamping of both Federal and State procedures to lessen the time interval presently required for the approval of projects, and the interval between the planning and construction of necessary projects, would aid in providing necessary flood protection.

The Commonwealth has a guiding interest in preventative control; i.e., flood-plain zoning. While the zoning powers are in the hands of the local governments in Pennsylvania, we have provided a manual for the use of interested local communities in establishing zones or areas based on hydrologic principles. A program at all levels, Federal, State, and local, is required to educate the public in the need for, and benefits afforded by, this type of protection.

The use of water for irrigation purposes is rapidly expanding in Pennsylvania. The amount of land under irrigation has doubled every 5 years, and because irrigation is a consumptive use, the problem is no small one. Frequent droughts, the availability of lightweight irrigation equipment and pipe, and the increasing realization of benefits to be obtained indicate that this practice will continue to expand. Another factor affecting this trend is the disposition of owners of costly irrigation systems to use them more and more frequently. A dual problem we face, therefore, is the securing of sufficient water supplies for irrigation and the development of a system of water rights that will protect the farmer's interest in consonances with the interests of all water users.

The use of vegetational treatments and the application of agronomic and structural practices on the land have definite effects on the quantity and quality of water released to the streams. No single activity is more important to watershed management than the development of forest fire protection in Pennsylvania during the last century. This has prevented widespread destruction of watershed cover and topsoil, and consequent damage from erosion, floods, sedimentation, and pollution. Forest fire protection on privately owned lands continues to be a watershed problem in the State. Education of woodland owners in methods of preventing forest fires and controlling injurious insects and diseases should be increased. Forests prevent soil from freezing hard in the winter, permit the penetration of moisture, and alleviate flooding in winter and spring. Accordingly, the tree-planting program on idle lands of the Commonwealth should be accelerated. This would include the treatment, leveling, and planting of strip-mined areas. Improved logging methods, better construction of logging roads prevention of cattle grazing in woodlots, and selective cutting to conserve water are all effective methods of reducing runoff, and all need additional research.

There is some evidence that, on occasion, substantial volumes of floodwater are made up of soil washed from farm fields and carried in suspension. Some research is being done by the Commonwealth in this field, but much more is necessary. The Special Advisory Committee on Soil and Water Research appointed by Secretary Benson last year recommended that several regional hydrologic research centers be established to make such studies. One is recommended for the Northeast, and it is urged that these recommendations be implemented through necessary appropriations.

Federal and State water projects are usually constructed with a single purpose in view. Each reservoir, however, is a valuable resource in its own right. We strongly advocate, therefore, that all future reservoir projects be studied from the standpoint of including all possible additional uses. High-quality reservoir sites should be placed in public ownership and future sites should be reserved while still available.

Our experience indicates that the development of water resources must be coordinated with soil, forest, wildlife, and mineral conservation. When larger drainage basins of major river systems are developed, as in the Corps of Engineer's study on the Delaware Basin, certain disadvantages in meeting local needs and wants are experienced along with the advantages of the broad view afforded. The Commonwealth's study and plan for the development of the water resources of the Brandywine Creek Basin in Pennsylvania, is an effort to fill this local need.

Machinery is needed on a State and National basis to secure the maximum development of natural resources of any region where local communities are not equipped to recognize the need and carry out the planning. The organization of citizen-directed watershed associations to plan and coordinate should be encouraged. Interagency cooperation is a must in any water development program to assure a comprehensive, balanced program.

In order to develop sound and comprehensive water resources plans, it is essential to have adequate hydrologic data. There is a need for more comprehensive and integrated studies which will indicate the interrelationship of both quality and quantity of surface and groundwater in the Commonwealth. For most efficient planning, there are certain functional studies which should also be made (flood frequency, low-flow frequency, etc.).

Any large-scale expansion of interpretive hydrologic studies will likely be limited by availability of qualified personnel. However, the greatest deterrent is the limitation of available funds, both State and Federal.

Recreation and fish and wildlife programs are all part and parcel with good and adequate water supplies. The Commonwealth's program, designed to place a State park within 25 miles of each Pennsylvanian, is well underway. It is evident, however, that the recreational needs and potential of our growing population are outstripping our construction of facilities. With a shorter workweek and more leisure time predicted for the future, every possible means of incorporating recreational use into existing and future projects; the development of fishing and boating facilities to the maximum; and protection of wildlife through, for example, the development of marsh pond areas and forest cover, should be investigated and encouraged.

In conclusion, we wish to state that if full consideration could be given to all problems, as outlined, in the development of our water resources, the result would be near Utopian. Yet, we are convinced that it will take near Utopian measures to assure adequate supplies of good water to meet all future demands, needs, and uses. Increasing population and industry, with all the attendant and companion needs of a growing prosperity, dictate that anything less may breed stagnation and subsequent retrogression.

We are further convinced that comprehensive planning and development of our water resources at all levels, taking all water uses, needs, and requirements, conflicting or otherwise, into consideration is the key to the problem.

A national water policy is sorely needed. Competition between agencies working on water problems should be eliminated because this is wasteful to the public purse and ultimate good. The development of water should be coordinated with the development of other natural resources.

RHODE ISLAND

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS,
EXECUTIVE CHAMBER,
Providence, August 18, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

MY DEAR SENATOR KERR: In reply to your letter of June 23, 1959, requesting information on Rhode Island's water problems, I am forwarding a statement in the matter supplied to me by the Rhode Island Water Resources Coordinating Board, also a copy of the latest engineering report obtained by the board.

It is hoped that this information will satisfy your immediate needs. Should you desire additional information in the future, I would suggest that you write to:

Walter J. Shea, chairman,
Rhode Island Water Resources Coordinating Board,
335 State Office Building,
Providence, R.I.

With best wishes.

Sincerely,

CHRISTOPHER DEL SESTO, *Governor.*

STATEMENT OF RHODE ISLAND WATER RESOURCES COORDINATING BOARD ON WATER PROBLEMS IN RHODE ISLAND, AUGUST 12, 1959

Water resources and the need for their proper conservation to meet future requirements have in recent years been of much concern to the State government of Rhode Island. This concern led to the establishment of a water resources study commission by an act of the legislature in 1951. The commission published a report of its engineers with the commission's recommendations, in 1952.

A successor, permanent, State water resources coordinating board was appointed late in 1955. Because of the timelag and changing conditions, the new board decided to have an updated engineering survey made of water resources, their conservation for public use, and feasible methods for their future development. The engineers submitted their report to the board in August 1957. This report pointed up potential reservoir sites on relatively unoccupied drainage areas and stressed that they should be preserved for future public drinking water supply development by State acquisition. It was recommended that action in the matter be taken as promptly as possible to avoid excessive costs of acquisition at a later time. In line with this recommendation, the board has engaged engineers who are currently making a field survey of two of the most desirable reservoir sites. It is the board's intention to follow up the field survey with a property value appraisal preliminary to a recommendation to the legislature of specific land acquisition. The board's long-range program calls for survey, appraisal, and recommendations for acquisition of other reservoir sites in the order of their ability to meet future public supply demands.

The board's engineers recommended the development of reservoirs and the construction of such appurtenant works as may be required to treat and transmit water at the time and in the order that the need develops. The engineering studies that have been made anticipate needs up to the year 2001 A.D. The 1957 report estimated public water consumption of 181.65 million gallons daily by 2001, for a State population of 1,211,200. (The 1950 census figure was 791,896. Average daily water use in 1950 was 70.44 million gallons daily.)

Existing surface and ground public water supplies of dependable yields which total 153.85 million gallons daily will fall short of 31.37 million gallons daily of meeting the demand in 2001. The apparent arithmetical error in computing the estimated deficit above is based in part on a supply deficit of 3.57 million gallons daily on the assumed eventual abandonment of four small reservoirs. Compilation of deficit and existing supply figure also takes into consideration since-completed or planned water projects to increase public drinking water supplies.

Progressive and flexible development of proposed reservoirs, the board feels, will more than meet the deficit estimated by 2001, if the program is carried out.

PROPOSED RESERVOIRS

Proposed reservoirs—one group in the west-central and the other in the northern part of the State—have a total potential estimated safe yield of about 103 million gallons daily, less compensation water. Cost of development of proposed reservoirs was estimated in August 1957 at $22,700,000 exclusive of land, easements, water rights, legal and administrative expenses.

WITHDRAWAL AND USE

The following figures on municipal water supply use in the State, furnished by the State division of sanitary engineering, do not include some institution and military use but cover the State's principal drinking water supplies and 99 percent of the overall consumption.

	Million gallons daily		*Million gallons daily*
1950	70.44	1955	80.64
1951	73.57	1956	81.76
1952	75.37	1957	85.64
1953	78.53	1958	77.90
1954	76.04		

POPULATION STUDIES

Both engineering studies received by the board made population projections. The 1957 report estimated a greater population increase than did the 1952 report. The 1957 report estimated the State population by the year 2001 at 1,211,000 and the water consumption at 181.65 million gallons daily, based on 150 gallons per capita per day.

MUNICIPAL WATER USE

A recent study by the Institute of Public Administration recommended to the fiscal study commission that the State take over all water supply systems in the State. The plan proposed leasing of Providence water properties, including the Scituate Reservoir. It should be noted that Providence officials take a dim view of the plan, saying it could be disastrous financially for consumers now serviced by the city-owned system. The recommendation, which the fiscal study commission has approved, suggests that the Providence Water Supply Board be "adopted" as a State division of water supply; that the Providence distribution system be extended without legal restriction; that the proposed State division buy or accept as gifts, other local water systems and operate them; that the division plan and encourage improvements in present water systems and develop new or extend systems; that the division develop long-range plans for the most efficient and economical means of conserving, developing, and transmitting the State's water supply. The report was based upon studies of engineering reports initiated by the State water resources coordinating board and the commission it succeeded.

INDUSTRIAL SURFACE WATER SUPPLIES

With the decline of the textile industry in the State, some mill reservoirs have been abandoned, drained, or have deteriorated badly because of decreasing use or misuse. Engineers have recommended consideration of the possibility of State acquisition of developed industrial supplies where abandonment may appear imminent, unless it would impose a prohibitive financial burden upon the State. It might be noted that several new industries have found ground water to supply their needs at sites where they have located.

GROUND-WATER RESOURCES

The State has cooperated with the U.S. Geological Survey since 1944 in ground-water studies which indicate ample potential supplies in some areas and little, or spotty, in rocky sections. Indications are that quadrangle (preliminary investigation) survey reports will be completed within a year. Collection of data started in October 1955 on the State's first quantitative and qualitative investigation in an area selected for industrial development. The survey shows promise of a potential yield of millions of gallons daily, U.S. geologists say. A report on this survey should be out in less than 3 years. Rhode Island publishes cooperative State-U.S. Geological Survey reports for more-or-less limited distribution. The board is cognizant of problems which might arise should large (industrial) users start drawing on the same ground-water source. To cope with this problem, the board since inception has discussed regulatory steps which might be sought should the issue arise.

WATER POLLUTION

Pollution control in Rhode Island, insofar as the treatment of municipal sewage is concerned, has reached a well-advanced stage. Only one sewered municipality in the State lacks adequate sewage treatment facilities. In this case, it is a matter of replacing treatment facilities which have been outgrown. Other States have reached, or are very close to reaching, a similar achievement. This, of course, does not mean that there is no longer a pollution problem in Rhode Island. Unhappily, large industrial waste producers, largely textile finishing plants, removed from municipal sewer systems, continue to cause serious water pollution. Most of these plants have adopted some kind of waste treatment system which reduces the pollution load discharged. The treatment provided is seldom equal to the need, and practical means equal to the need have not been developed.

There are other aspects of the pollution problem which are obstacles to the realization in Rhode Island, of the benefits of clean water, benefits so much desired. In the older cities of the United States, where combined sewer systems are common, the disposal of sewage contaminated storm water beyond the capacity of feasible treatment facilities, continues to plague pollution control authorities.

It is understood that in the District of Columbia, a long-term program of separation of storm water from sanitary sewage will be undertaken. This, of course, involves a tremendously large expenditure and will take many years to accomplish. It is unlikely that many communities will readily undertake such a radical and burdensome solution such as this.

The sewage disposal problems connected with suburban development are increasing rapidly here, as in many other places. Such development makes the installation of small sewage treatment plants a necessity; resort to such plants can no longer be postponed in many areas. There appears to be little hope of installing municipal sewers in many suburban areas in anticipation of suburban growth. These small plants, perhaps package plants, will have to serve until installation of a comprehensive system of sewers is justified economically.

FLOOD CONTROL

Flood control damage in Rhode Island has been greatest from high water accompanying hurricanes, although serious flooding from heavy runoff has been experienced in the Blackstone River drainage basin.

Plans to erect upper Narragansett Bay hurricane barriers are well advanced. Lower bay barrier plans are still under study by the Corps of Engineers. Channel improvements and floodwall protection have been developed on the Blackstone River in the city of Woonsocket; flood control reservoirs upstream in Massachusetts are planned.

SOUTH CAROLINA

State of South Carolina,
Executive Department,
Columbia, January 25, 1960.

Mr. Theodore M. Schad,
Staff Director, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Mr. Schad: Governor Hollings has just appointed the Water Policy Study Group which is making a comprehensive investigation of water resources and problems in South Carolina. Therefore, the Governor plans to offer his suggestions to your group upon the completion of their study.

We regret the delay in responding to your earlier correspondence but we look forward to getting the Governor's statement in to you within the next 2 or 3 months.

Sincerely,

S. Ernie Wright, *Industrial Secretary.*

Summary of Water Problems in South Carolina Based on Testimony and Statements Presented to the Committee at a Hearing Held in Columbia, S.C., on May 13, 1960

By Ernest F. Hollings, Governor of South Carolina; Walter W. Harper, Director, State Development Board; W. T. Linton, Executive Director, Water Pollution Control Authority of South Carolina State Board of Health

South Carolina is in a remarkably fortunate position for water supply and has not experienced the water shortage which has plagued so many of the Nation's less fortunate States. The State has, however, begun making plans to protect its water resources and to utilize them wisely and efficiently. In 1953 a special water policy committee was formed by the general assembly to study and make recommendations for a policy for the State. The committee report outlined the quantity and quality of the State's water resources, water usage by industry, agriculture, municipalities, and others, and many other facets of the subject. The committee proposed a policy for the conservation, control, and regulation of the waters of the State. The policy has not yet been enacted into law.

According to the Governor it was found that there is disagreement concerning the best water policy, but there is unanimity of opinion that a State agency should accumulate more technical data on South Carolina's water resources and uses, and that projections be made for future short- and long-range needs. The Governor's statement recommended that this and other responsibilities related to the State's water resources should not be the responsibility of the Federal Government. The Governor is prepared to propose to the general assembly the establishment of a State water resources board to coordinate all of the State's water resources activities such as: use and development of streams and rivers, quantity and quality control, water pollution control, negotiations with Federal and other State governments, and other responsibilities which may be assigned.

According to the Governor's statement—

> We in South Carolina feel strongly that administration of our water resources is a matter for the State and not the Federal Government. We believe that we know more about our problems concerning water here at the local level than any individual or group in Washington. We are making an intelligent, concerted effort to seek the solution to water resource problems in South Carolina and to plan effectively for our future needs and uses. Water plays such a vital role in our economy that we must be left free to plan its uses to the maximum benefit to our citizens and to our economy.

The State development board is especially concerned with the relation of South Carolina's water resources as a whole to prospective industry that may be attracted to the State. The director of the State development board points out that there is a great demand for industrial sites with sample water supplies, but notes that desirable industrial sites are lost when large areas become flooded by Federal projects. The board is vitally interested in seeing that these excellent industrial sites throughout the State be preserved so that water-using industries may be attracted into the State. The board heartily endorses any plans that propose the positive protection of the economic potential of communities within the State.

The executive director of the water pollution control authority notes that—

> Pollution control is an expensive undertaking. Yet the expenditures that are necessary to accomplish this task can, and must, be justified by the maintenance of generally satisfactory health conditions, and also from the economic benefits which will be derived therefrom.

The director points out that the most critical aspect in the entire matter of water resources is the lack of visionary planning, based on a foundation supported by the collection and evaluation of basic data. Such planning can be accomplished today and for the future only through a cooperative effort of all users, predicated on the recognition and understanding of the problem as it affects all interests.

He suggested that consideration be given to the possibility of expanding the potential of the U.S. Public Health Service to the degree that it can cooperate with the States and such interstate agencies which now exist or may be created, in the production of a plan for the orderly development of the water resources of this country.

In concluding, he made the request—

> * * * that nothing be done in Congress because of the recommendations of the Select Committee which would in any way restrict the beneficial uses of the waters in the State by its citizens.

SOUTH DAKOTA

Office of the Governor,
Pierre, S. Dak., October 24, 1959.

Hon. Robert S. Kerr,
Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

Dear Senator Kerr: By letter dated June 23, 1959, you requested a statement concerning water problems in South Dakota, both present and anticipated to arise between now and 1980.

The statement requested is attached hereto.

Thank you for the opportunity to comment upon these matters.

With kind personal regards.

Sincerely and cordially,

Ralph Herseth, *Governor.*

Water Supply Problems and Future Water Needs

This report is prepared in response to a request addressed to Governor Ralph Herseth, South Dakota, dated June 23, 1959, from Senator Robert S. Kerr, chairman, Select Committee on National Water Resources.

This report consists of a summary of present water supplies and uses in South Dakota, water supply problems associated with present and future water uses projected to 1980, and water resources developments needed to satisfy future water supply requirements. Supporting information is attached to this summary.

South Dakota is predominately an agricultural area. The sizable tourist business, mining and light industry, while of increasing importance to the State's economy, are dwarfed by the stock producing and farming enterprises. It is expected that the same economic relationships will exist in 1980.

Stabilizing the overall agricultural industry with adequate attention to broadening other economic and recreational pursuits and supporting urban services are the primary objectives facing the people in the State during the next 20 years. Water resources developments are important factors in the accomplishment of these objectives.

Geologic and climatic forces have produced the basic economic natural land and water resources in South Dakota which have been and are to be adapted to the American way of life in this area.

These forces have provided four general economic areas in this State. Each area has natural potentialities and deficiencies. The framework of development of the predominately agricultural potentials has been established. Optimum realization of these potentials for benefit of national, regional and local economies rests with correction of the deficiencies. These four general economic areas are indicated in color on the attached sketch map.

EASTERN AREA

The eastern area has good tillable soils and the most dependable water supplies in South Dakota. Here general farm crops and livestock feeding, presently provide the most stable economy in the State. This area has the greatest population density. Deep artesian groundwater exists under much of the land. Shallow groundwater is present in old glacial meltwater channels throughout this area. These glacial channels are generally coincident to present stream valleys. Irrigation quantities may be obtained from single wells tapping the larger concentrations of these shallow aquifers. Remaining portions of these aquifers are used extensively for household and stockwater use. Most urban water supplies are obtained from this source. Two major streams drain surface waters. Base flows in late summer season approach zero. This eastern area of the State contains the natural lake region in South Dakota. Much of the northern portion contains the "pothole" depressions typical of recent geologic glaciation. The deeper, more permanent of these depressions constitute lakes. The shallower ones are marshy slough areas. During wetter years, hundreds of these water surfaces exist. Only a few contain water during normal dry cycles. These depressions are great migratory waterfowl natural breeding and migration areas. Pheasant, deer and other wildlife are prevalent in this eastern area.

Water problems are primarily unpredictable variability of precipitation, floods and questionable chemical quality of the deep groundwater. This eastern area is approximately 50 miles wide. Average annual precipitation totals about 30 inches along the eastern fringe to 20 inches along the western fringe. However, 50 to 10 inches variations may occur and 5-year wet or dry cycles are not unusual. Damaging floods coincide with wet years, the degree of damage being closely related to the amount of annual precipitation and the intensity of individual storms. Snowmelt floods originate in the upper basin. In addition, June rains constitute an additional hazard in the southern portion of the area. Land erosion, caused by surface water runoff, is a serious problem, especially in the highly erodable soils and steep slopes in the southern portion. Fluctuating levels of lakes and sloughs and losses of "pothole" areas by farm land drainage is a serious threat to wildlife, especially migratory waterfowl.

Water resources developments should be directed toward control of floods by storage of water to the maximum extent possible. Storage sites on the two principal streams are scanty, so flood control storage on tributaries offers best solutions. Land erosion control should be associated with such tributary developments. Conservation storage of water should be included in such reservoirs to provide seasonal use for domestic, municipal, industrial, and irrigation water supplies. Deep ground water has deficiencies as to quality since it contains up to 3,000 parts per million of dissolved salts. Where such water exists (most of the eastern area) future stockwater supplies may be obtained from this source. This water should not be used untreated for human consumption (especially in the northern portion) except as a last resort. Industrial use is limited to such uses compatable with dissolved chemicals. This water is unfit for irrigation. Correction of deficiencies in this water lies in economical desalting methods. Shallow ground water is not universally available, but where it can be obtained (copious quantities in many places) it is generally satisfactory for all uses. Regulation and control of use is mandatory to limit uses to the amounts of average annual recharge. Otherwise these water sources can be easily "mined," thereby destroying their usefulness for all. The special wildlife values in this area, especially migratory waterfowl, should be preserved and enhanced. Basically, purchase of "potholes" and importation of additional water are prerequisites. The only adequate source for importation of needed additional water supplies is the Missouri River. Reasonable precipitation increases through weather modification would be helpful for all water-use purposes. It is doubtful that seasonal timing of precipitation could be helped by rain increasing operations. Recreation use, including wildlife propagation, can follow water supply developments for other purposes. Presently, there is great need and demand for water recreation areas in this greater population density area of South Dakota. Water pollution is not serious now. Continuing efforts are necessary to maintain satisfactory pollution relationships. Water supplies for other purposes will provide sufficient dilution water. Without such supplies, pollution will reach serious proportions.

EAST CENTRAL AREA

With water supply increases, this area offers the greatest increased potential in the State and can become the greatest stabilizing factor for the dry land stock-producing and stock-feeding agricultural enterprises. Here sufficient potentials exist to produce all additional winter-feed for maintenance of the breeding stock, commercial stock and stock feeding operations in the State. Lack of assured stock feed supplies annually is, perhaps, the greatest single economic factor for agricultural stability and results in use of marginal lands (compared to other regions of the United States) for cash crop production, usually the types of crops in "surplus" at the present time. The solutions rest with increased water supplies.

This area has extensive, relatively flat farmlands with good tillable soils. Moving west across this area, farmland use merges into stock production. Deep artesian waters, easily obtained, underly the entire area. Chemical quality is not good, but such ground water is used extensively for domestic, municipal, and stock water supplies. Fair quality shallow ground water in glacial melt water channels is widespread. Irrigation quantities are obtained in some areas. Streamflows are seasonal with zero flows occurring during late summer periods almost every year. A few natural lakes exist. Local organizations and State agencies have built facilities to maintain and add water supplies to these lakes. Recreational and waterfowl reservoirs have been built where feasible but levels of natural and manmade water areas are almost impossible to maintain during the many less than average rainfall years. This area is the home of the pheasant.

Water problems are numerous. Average annual precipitation is 16 to 20 inches, west to east. However, the average seldom occurs. During the many dry years, annual precipitation is in the neighborhood of 12 inches with attending crop failures. Wet years produce 25 inches with attending floods. Seldom is there a good early summer crop and a good late season crop during the same year. The variable seasonal distribution of precipitation is poor and occasionally results in the paradox of poorer crops during wetter years than are obtained during dryer years. Quality of much of the ground water is brackish, though used of necessity. Quality of late season streamflows is poor and some serious instances of pollution exist. Correction is difficult because of scanty water supplies. This area is a water deficient transition between subhumid and semiarid regions. Scanty and extremely variable water supply, occasional floods, poor quality; these are the water problems of this area.

Importation of water from the Missouri River will correct many water problems. This is proposed in the Missouri River development program for irrigation purposes. The many needs for water may be served as incidental purposes but no Federal program other than irrigation covers such alleviation of water shortage problems. Flood and erosion control projects are needed. Conservation storage should be included in these projects. Economic desalting processes would solve the ground-water quality problem. Regulation and control of ground water use is mandatory since the deep ground water supplies have been "mined" to an appreciable extent during the past 60 years and is only now reaching a much lower equilibrium condition. Precipitation increasing through weather modification would be a boon to this entire area. All uses of water in this area suffer serious shortages under present conditions. Economic stabilization and associated human values are utterly dependent upon new water supplies, the only known source of which is the Missouri River. It is well to remember that the "bare existence" agricultural standard in an area such as this produces a reluctance to change, to upset the applecart so to speak. Local willingness to sponsor projects or to accept additional obligations are slow under such conditions.

WEST CENTRAL AREA

This is the great grasslands, stock producing region of South Dakota. East of the Missouri River the land has been glaciated and soils are good. Considerably dryland farming exists here. West of the Missouri River soils are generally poor for farming although scattered areas are present. Most of this area has never had the native sod plowed. Except for recurring dry cycles, the native grass cover makes excellent grazing land. Deep artesian ground water underlies this entire area but it is relatively expensive to develop. Shallow ground water exists in scattered locations in the glacial drift east of the Missouri River but is confined to the alluvial stream valleys west of the river. Except for the Missouri River and the Cheyenne River, all major streams produce water of questionable quality for irrigation use and most have no flow during late summer and fall periods of each year. Runoff is rapid, consequently snowmelt and flash floods are fast moving, short duration occurences. Floodflows are much better qualitywise. Except on the upstream reaches of the Cheyenne River and one other questionable instance, reports, concerning project-type development of the water resources of these western tributaries of the Missouri River, are unfavorable for either flood control or irrigation. Surface runoff waters are used extensively for stockwater. Approximately 70,000 stockwater reservoirs have been built in this area. During recent years, spreading the runoff waters from dry draws over hay meadows has become common practice. Hauling stock and domestic waters are not unusual especially during dry years.

Precipitation averages 12 to 16 inches in this area. Scanty precipitation and extreme variability, both annually and seasonally, are the water supply difficulties. The greatest problem for the stock grower is winter feed supplies. About one-fourth of the grazing land is reserved for hay. Normally this produces sufficient winter hay for both commercial and breeding herds. Carryover supplies for 2 years is widely practiced, however, a single drought year results in the necessity to dispose of commercial stock by many operators. Two successive years of drought threatens maintenance of breeding herds. The latter is the real worry for the stock producer because replacement of brood stock is expensive and difficult because of the widespread prevalence of shortages.

Project-type water resources developments are not usually feasible in this area under present feasibility measuring standards. Two federal projects, two probable Federal projects, and two project-type private developments seems to have exhausted the feasible possibilities. Small near-headwaters stockwater reservoirs are vital, not only to water stock but to permit reasonably uniform grazing of lands and to prevent overgrazing. Care must be exercised to provide proper spacing, damsite selection, size and depth for such reservoirs. Stock winter feed supplies must be stabilized to realize the economic potential of this area. The source of such feed during drought years can come from the east central area of South Dakota with irrigation development. Still further stock producing potentials can be realized by producing winter feeds on east central irrigated lands rather than harvesting native hay on grazing lands. This area, with its sparse settlement, has abundent wildlife. This characteristic will continue, probably, through 1980 with local habitat development. One exception may be difficult to solve. The large scale flooding of Missouri River bottom land by reservoirs has eliminated the natural habitat of many, many wild creatures. It is doubtful that they can adapt to the changed conditions. It is doubtful, also, that replacement habitat can be provided at this late date.

BLACK HILLS AREA

This is the forested, mountainous area of South Dakota. Its economic development centers around mining, timber, stock production, and the tremendous tourist attractions of the Black Hills. Precipitation averages 20 to 30 inches annually. However, much of the runoff in streams is lost in exposed limestone and sandstone outcrops. While not completely explored geologically, this loss of surface water is considered to be recharge to deep artesian aquifers extending under most of South Dakota.

Water problems in this area are adequate supplies at sites of recreational attraction and mining potentials. All surface waters flowing from this area have been appropriated, primarily for irrigation purposes. Stockwater is very scanty around the outer fringe of this area. Concentrated municipal water supplies have been difficult and expensive to develop and will become more so. Some recreational lakes have been constructed. The demand for more is strong.

Water resources development should be concentrated on conservation storage for recreation, municipal, mining and irrigation purposes. Works to bypass streamflow loss areas are needed to supply fringe area domestic and stock water supplies. Preservation and enhancement of the natural recreational values of this area should be considered in all water development plans.

A tabulation of water needs, water supplies, and rough estimates of water resources development investments for the various purposes is attached.

Informative charts showing climatic conditions and Federal irrigation potentials are attached also.

And additional supporting material is submitted with this summary. Further information is available if desired.

South Dakota water needs projection (acre-feet annually)

	1959					Estimated as of 1980				
	Number	Water delivery	Consumptive use [2]	Estimated investment in works [1]		Number	Water delivery	Consumptive use [2]	Estimated total investment in works [1]	
				Non-Federal	Federal				Non-Federal [3]	Federal [4]
Population:										
Rural	300,000	30,000	5,000	$50,000,000	0	300,000	40,000	7,000	$150,000,000	0
Urban	400,000	50,000	7,000	25,000,000	$2,000,000	580,000	130,000	16,000	105,000,000	$4,000,000
Livestock:										
Cattle	3,400,000					4,200,000				
Sheep	1,600,000	600,000	400,000	8,000,000	6,000,000	2,000,000	600,000	400,000	40,000,000	30,000,000
Pigs	2,900,000					3,600,000				
Irrigation:										
Conventional	140,000 acres	300,000	200,000	6,000,000	16,000,000	500,000 acres	1,300,000	900,000	26,000,000	250,000,000
Spreader systems	50,000 acres	30,000	25,000	700,000	1,800,000	100,000 acres	60,000	50,000	1,700,000	4,000,000
Industry (other than urban)		4,000	1,000	800,000	0		50,000	8,000	19,000,000	0
Electric energy:										
Commercial	350,000 kilowatts	[5] 4,000	[5] 1,000	28,000,000	102,000,000	800,000 kilowatts	[5] 20,000	[5] 3,000	158,000,000	240,000,000
Irrigation	0 [6]	0	0	0	0	80,000 kilowatts	[6] 0	[6] 0	[6] 0	54,000,000
Navigation (Sioux City, Iowa-Yankton, S. Dak.)		0	0	0	0	80 miles	(7)	(7)	0	80,000,000
Flood control:										
Rivers (Big Sioux, Vermillion and James Rivers).				1,600,000	10,000,000				7,000,000	40,000,000
Watersheds	50,000 acres (3)			400,000	600,000	1,000,000 acres (12)			8,000,000	12,000,000
Water recreation:										
Natural lakes	152,000 acres (108)	500,000	450,000	200,000	0	152,000 acres	500,000	450,000	600,000	0
Manmade lakes [8]	18,000 acres (129)	60,000	54,000	2,500,000	0	21,000 acres	70,000	63,000	4,500,000	0
Wildlife:										
Natural areas (large sloughs)[9].	38,000 acres (164)	120,000	115,000	400,000	0	40,000	120,000	115,000	1,700,000	2,000,000
Manmade areas [10]	200,000 acres (239)	30,000	25,000	6,000,000	5,000,000	275,000 acres	70,000	60,000	13,000,000	10,000,000
Waste disposal:										
Conventional	74 plants	(11)	0	20,000,000	0		(11)	0	26,000,000	3,000,000
Sewage stabilization ponds	650 acres (58)	(11)	2,000	1,200,000	0	1,200 acres	(11)	4,000	1,900,000	300,000
Totals		1,728,000	1,285,000	160,800,000	143,400,000		2,960,000	2,076,000	562,400,000	729,300,000
Increase							1,232,000	791,000	400,600,000	585,900,000

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[1] Rough estimates. Excludes operation and maintenance costs which would be a variable but large proportion of investments.

[2] Includes evaporation, exclusive of Missouri River main stem and other Federal reservoirs.

[3] Includes replacements.

[4] Includes allocated costs of Federal projects.

[5] Exclusive of Federal and private hydropower plants.

[6] Included in commercial energy.

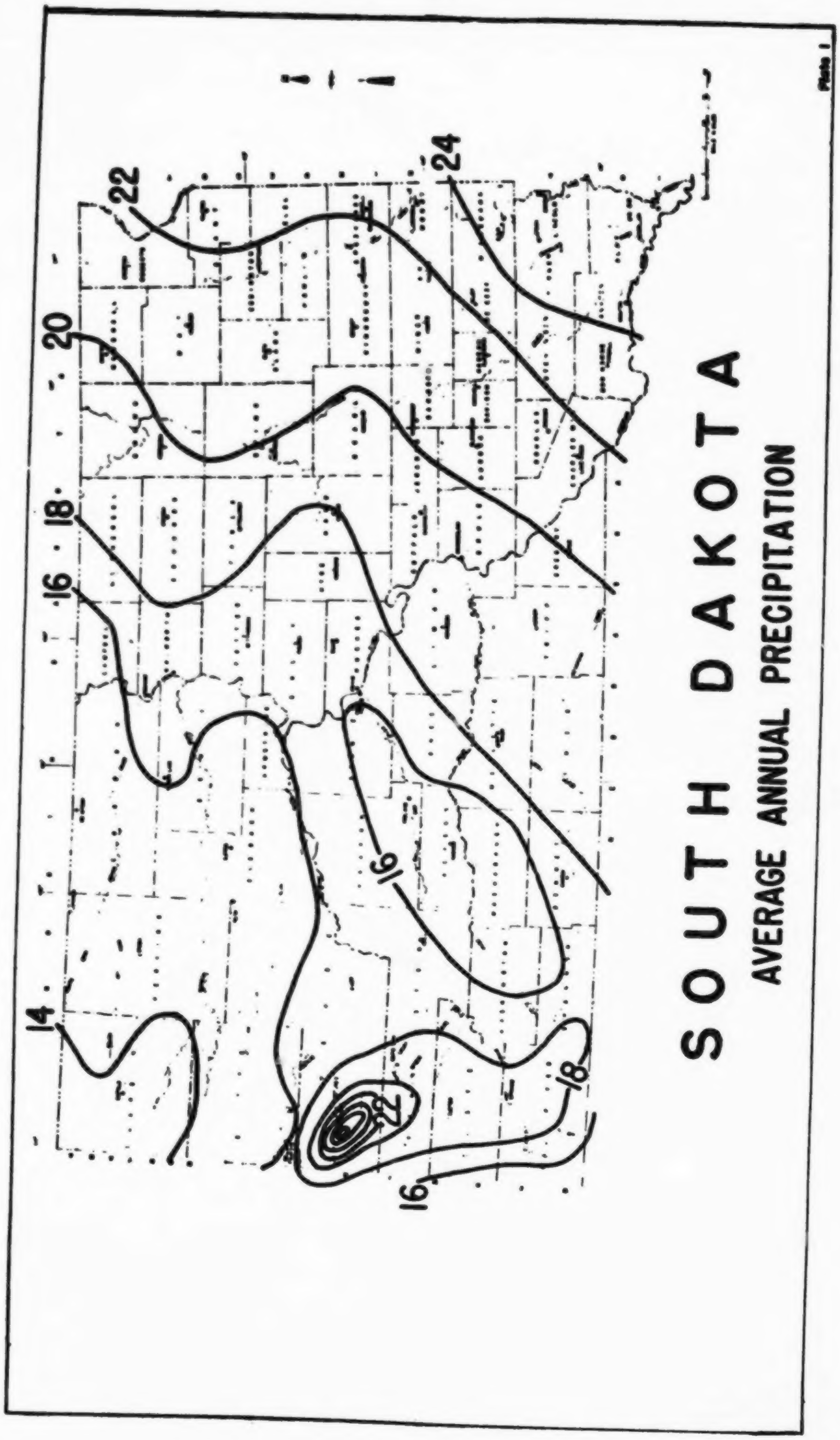
[7] No additional water.

[8] Exclusive of Federal reservoirs.

[9] Exclusive of pothole depressions and small sloughs.

[10] Exclusive of Federal areas and about 80,000 stockwater ponds.

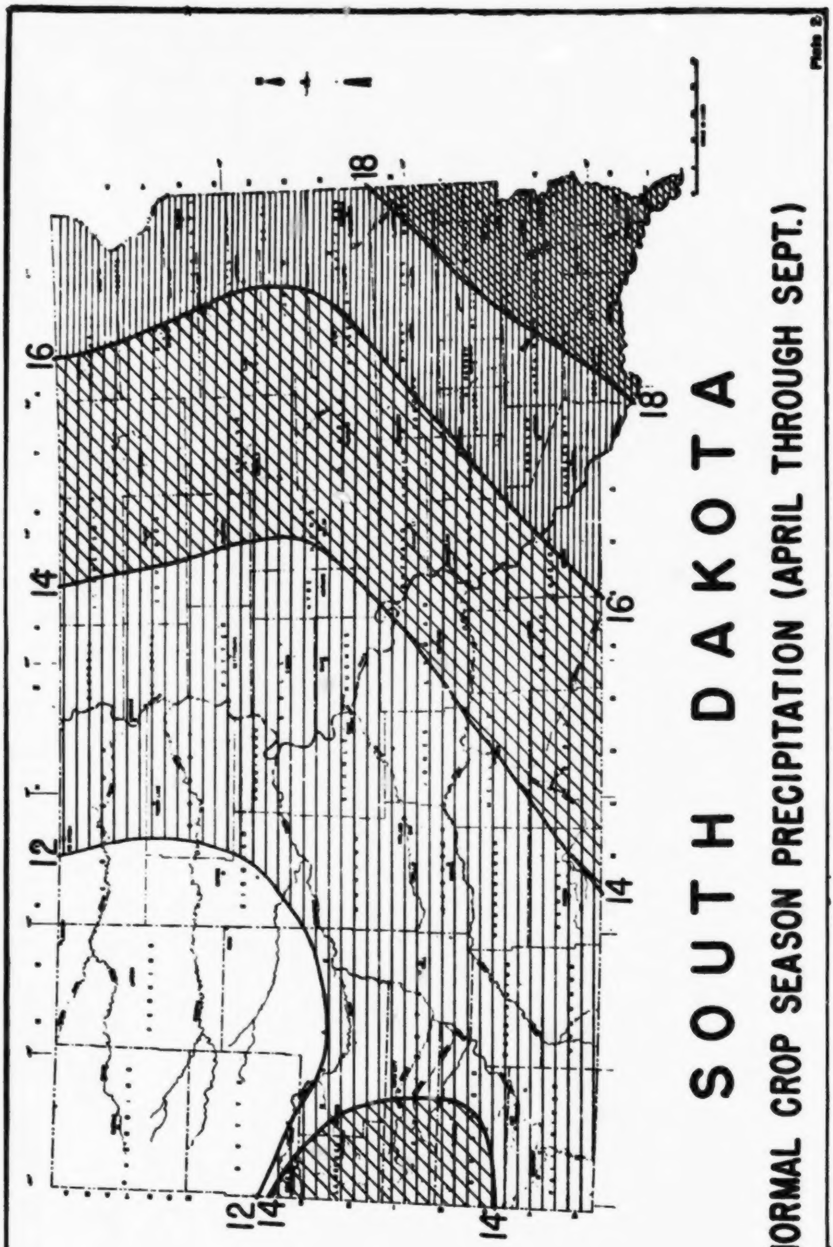
[11] Included in municipal (urban) needs.


14
16
18
20
22
24
16
22
18
16
Plate I

SOUTH DAKOTA

AVERAGE ANNUAL PRECIPITATION

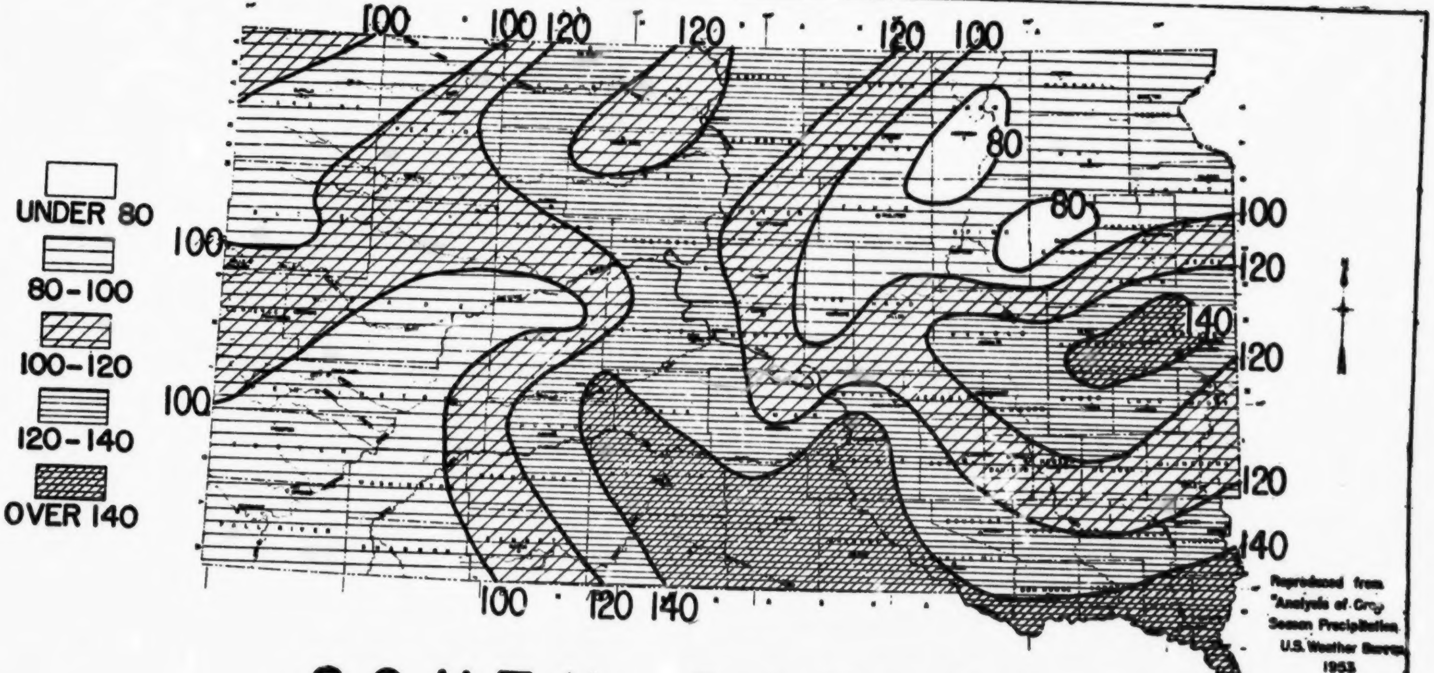
Reproduced from best available copy.


UNDER 12
12–14
14–16
16–18
OVER 18
12
14
16
18
Plate 2

SOUTH DAKOTA

NORMAL CROP SEASON PRECIPITATION (APRIL THROUGH SEPT.)

TYPICAL "WET" YEAR


UNDER 80
80-100
100-120
120-140
OVER 140
100
100
120
120
120
100
80
80
100
120
140
120
120
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100
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100
120
140

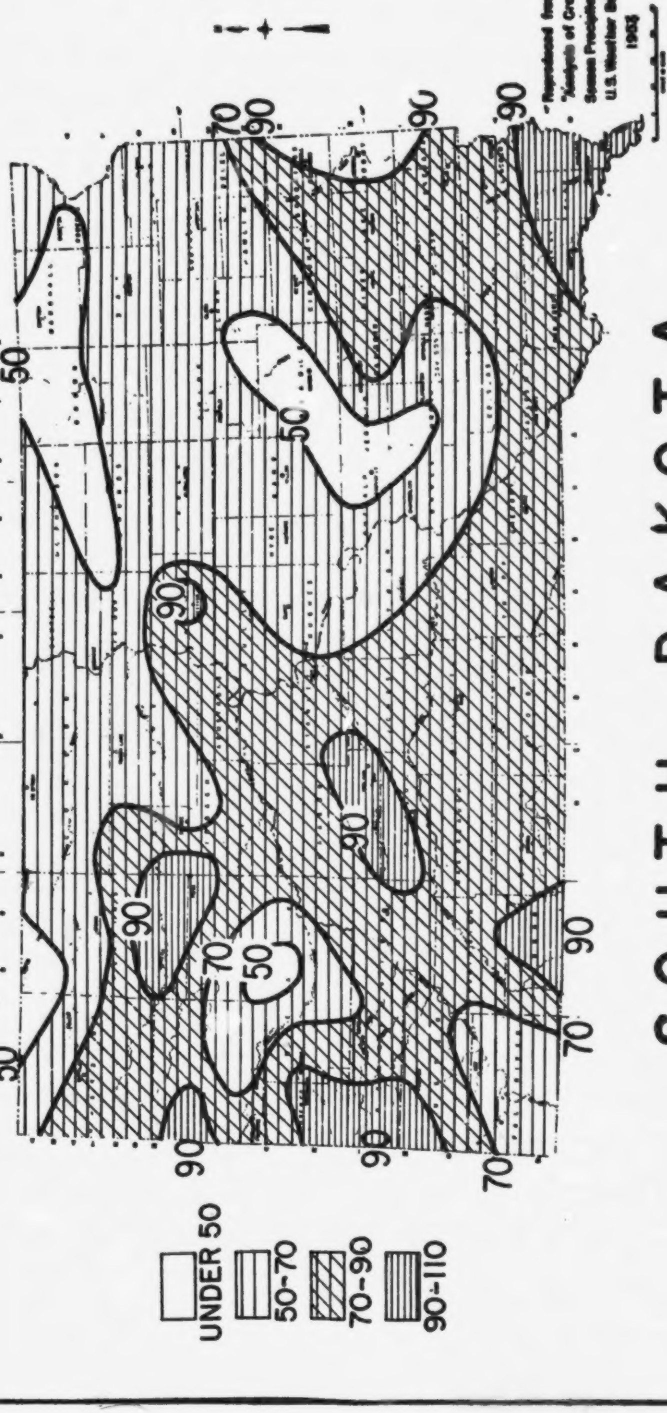
Reproduced from "Analysis of Crop Season Precipitation U.S. Weather Bureau 1953

SOUTH DAKOTA

PERCENT OF NORMAL CROP SEASON PRECIPITATION 1951 (APRIL THROUGH SEPT.)

Plate 3

TYPICAL "DRY" YEAR


UNDER 50
50-70
70-90
90-110
50
70
90

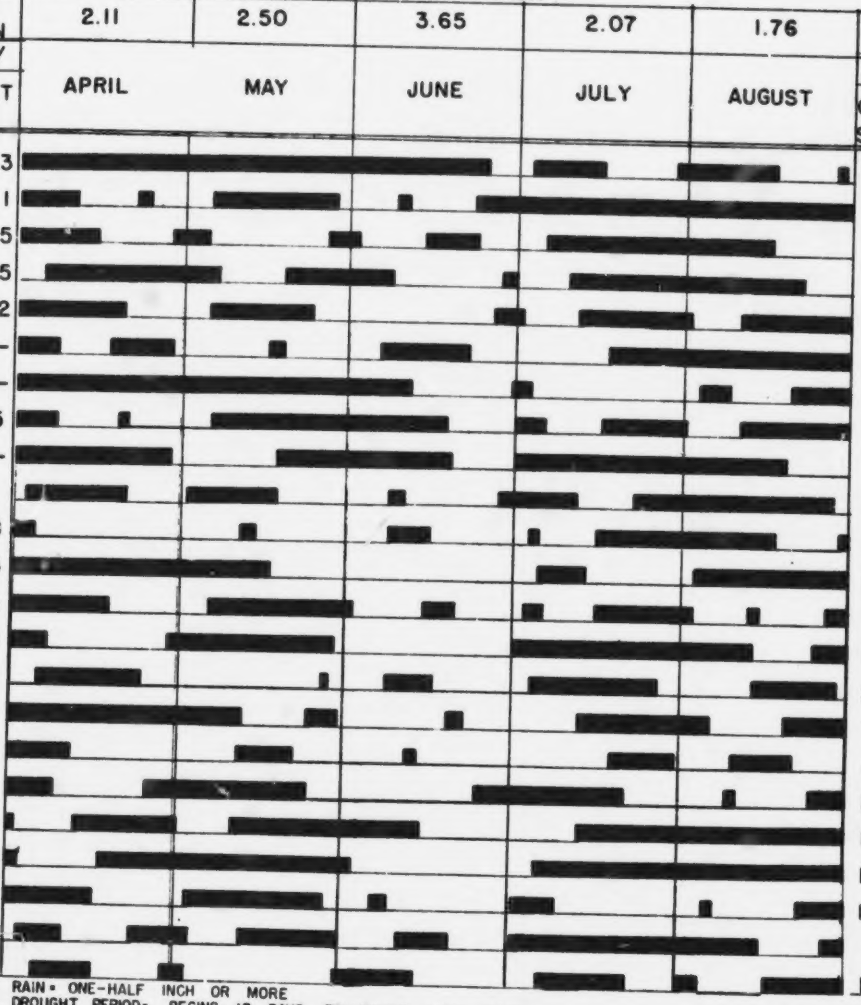
SOUTH DAKOTA

PERCENT OF NORMAL CROP SEASON PRECIPITATION (APRIL THROUGH SEPT.)
1952

"Reproduced from "Analysis of Crop Season Precipitation" U.S. Weather Bureau 1953

Plate 4

CROP YIELDS — SUMMER DROUGHTS — PRECIPITATION
MILLER-VAYLAND AREA



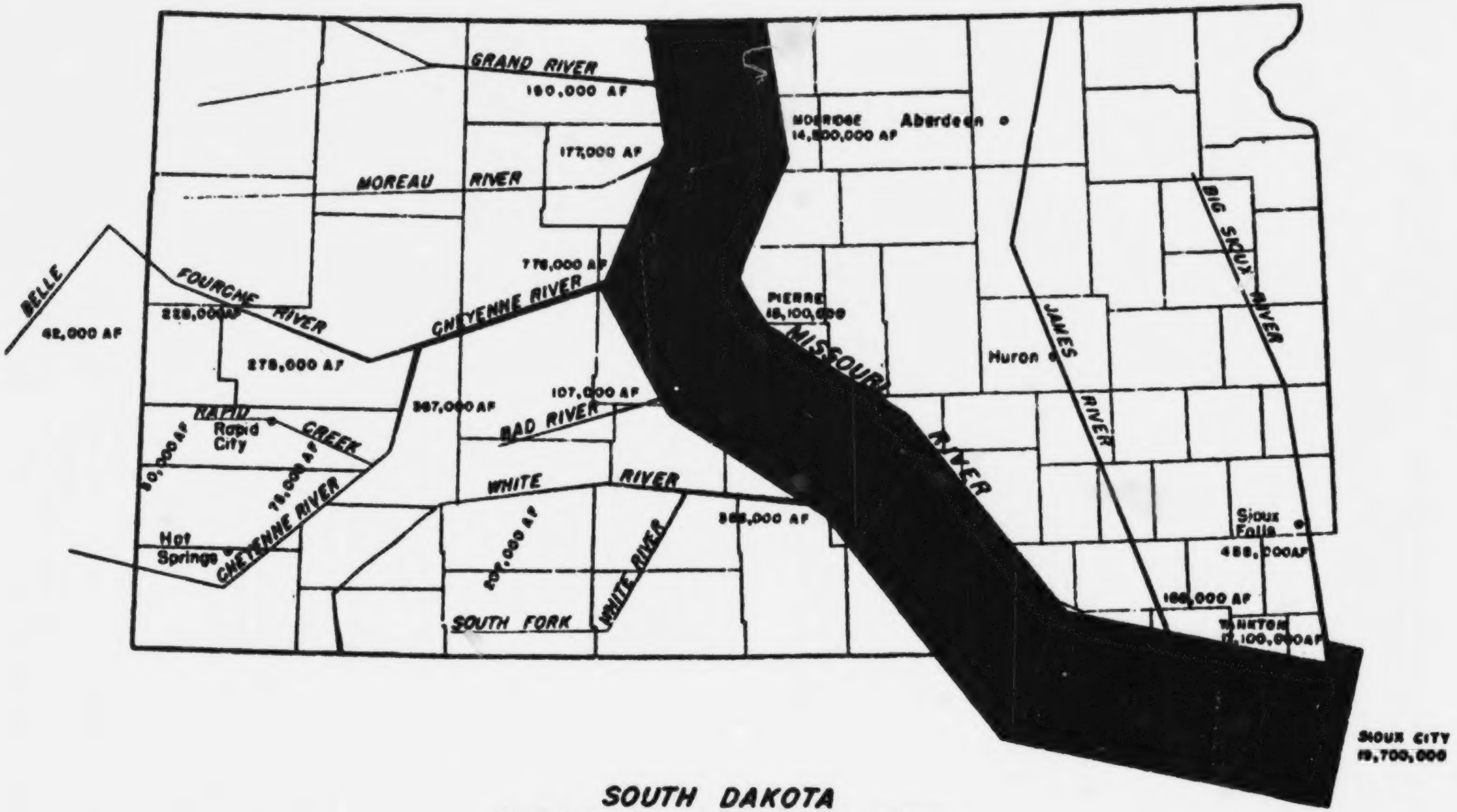
YEARS	YIELDS 1/ CORN BU.	YIELDS 1/ WHEAT BU.	PRECIPITATION GROWING SEASON	PRECIPITATION CROP YEAR
1928	8.6	7.3	10.17	14.01
1929	9.0	9.1	7.89	13.83
1930	12.6	11.5	13.46	19.72
1931	0.9	3.5	6.40	13.22
1932	6.8	12.2	10.75	15.99
1933	0.5	—	11.12	16.72
1934	0.2	—	9.05	12.49
1935	7.3	6.5	11.50	16.61
1936	1.8	—	6.62	9.08
1937	4.6	3.1	11.16	15.94
1938	6.0	8.0	14.10	18.16
1939	6.0	8.3	14.44	20.49
1940	7.7	10.3	8.30	14.08
1941	3.9	11.0	13.63	17.84
1942	26.0	11.5	21.33	32.67
1943	13.0	8.0	15.25	19.08
1944	26.0	8.7	18.09	24.82
1945	21.0	16.0	13.01	19.20
1946	24.0	13.5	11.75	17.33
1947	12.5	14.5	11.57	22.70
1948	28.0	12.5	14.05	21.77
1949	10.0	8.0	9.36	13.36
1950			14.80	23.53

ASSUMPTIONS: RAIN = ONE-HALF INCH OR MORE
DROUGHT PERIOD = BEGINS 10 DAYS FOLLOWING LAST RAIN

1/ SOUTH DAKOTA CROP AND LIVESTOCK REPORTING SERVICE

LAND USE UNIT APRIL 1951

PLATE 6


GRAND RIVER
180,000 AF
MOBRIDGE
14,800,000 AF
Aberdeen
177,000 AF
MOREAU RIVER
BELLE
FOURCHE RIVER
62,000 AF
228,000 AF
278,000 AF
776,000 AF
CHEYENNE RIVER
PIERRE
18,100,000
MISSOURI RIVER
Huron
JAMES RIVER
BIG SIOUX RIVER
367,000 AF
107,000 AF
BAD RIVER
RAPID CREEK
Rapid City
50,000 AF
75,000 AF
CHEYENNE RIVER
Hot Springs
WHITE RIVER
365,000 AF
207,000 AF
WHITE RIVER
SOUTH FORK
Sioux Falls
488,000 AF
166,000 AF
YANKTON
17,100,000 AF
SIOUX CITY
19,700,000

SOUTH DAKOTA
AVERAGE ANNUAL STREAM FLOWS

South Dakota's Water Situation—Present and Future Agricultural Water Supplies

The State of South Dakota is strategically located agriculturally in the northern portion of the North Central States region. It is located in an area of fluctuating annual precipitation ranging from 12 to 30 inches of moisture for a 12-month period as recorded during the past 30 years. Due to the distribution of the precipitation, a considerable portion of the water available for the State is lost by runoff and evaporation. This brings us, as inhabitants of the State, face to face with the problem of available and usable water resources for any given period or any one year.

South Dakota, being basically and primarily an agricultural State, is vitally dependent upon its water resources and the conservation thereof for the very existence of its agriculture, which includes grain, forage, livestock, horticultural crops, and domestic use. Fundamentally the agricultural water problems of the State revolve around annual precipitation, rainfall distribution, surface water supply, ground water storage facilities, and the very use of this aforementioned water by the inhabitants of the State and their dependency upon agricultural crops and livestock for an occupation and livelihood. It is with this pattern of water-use cycling that makes it imperative that something concrete be established in the very near future for an expanded water supply, distribution, storage and use program in the State of South Dakota.

At the present time, the water resources available and being supplied to the State are in the form of surface water and ground water. The current principle need for water in the State is for irrigation and livestock use. In South Dakota, the only major surface water supply with any degree of dependability and stability is the Missouri River. There are other major streams and tributaries in the State, but they have proven to be unreliable for any extended large scale use. This has certainly been apparent and demonstrated again during the drought of 1959 when most of the major streams had very little or no waterflow after midsummer.

In western and central South Dakota, a comparatively recent trend has been established, and certainly is expected to continue, in the construction and development of storing surface runoff water for livestock use. Along this same line of thought in the western part of the State has been the trend toward spreading of surface runoff onto hay and pasture land by means of diversion dams and ditches. An increasing number of inquiries together with many known installations the past few years have also been made to the South Dakota State College Experiment Station concerning the establishment of farm ponds to supply water for domestic farm use.

Shallow ground water (less than 200 feet) is found throughout the State; however, reliable supplies are lacking in many areas, particularly in the west-central portion of the State. Over 80 percent of wells in existence in the State are of the shallow well type and have a limited supply of yield primarily sufficient for farm use other than for irrigation purposes. Certain areas in east-central and eastern South Dakota contain alluvial and outwash deposits where large flows of water may be obtained, and these deposits supply water for most of the States' irrigation wells. Practically all of the irrigation wells in existence today have been drilled in the last 6 years.

A large portion of the western three-fourths of the State of South Dakota has deep ground water available falling in the artesian category. Wells that have tapped this source are as deep as 2,500 feet and very recently one was put down to a depth of over 4,000 feet in order to obtain an artesian flow from a previously untapped source. Exclusive of the Black Hills area, where much of the State's artesian water originates, practically all of this water is presently unsuitable for irrigation purposes due to poor quality and relatively small flows. As the years have gone by, artesian heads have steadily declined as an increased use of this source of water has been established.

Of all the water currently consumed in South Dakota, over 70 percent is being used for agricultural purposes. In this category water for irrigation and livestock represents the two largest users. At the present time there are approximately 140,000 acres of South Dakota soil under irrigation which represents about 0.8 percent of the State's cultivated land. Approximately 60 percent of this irrigated land is located in four organized districts in western South Dakota with private pump irrigation accounting for the remainder. Approximately 85 percent of the water used for irrigation purposes comes from surface-water supplies with irrigation diverting approximately 75 billion gallons annually. Rural and farm uses in the field of agriculture other than for irrigation purposes consumes about 30 billion gallons a year. Of this amount, approximately 22 billion gallons are used by livestock and obtained mainly from surface-water supplies.

Concerning the State's water supply, several fundamental problems are evident in the State such as reoccurring droughts with subsequent runoff possibly being the major problem in connection with water for agricultural use. Other pertinent difficulties arise as the cost increases in obtaining ground water from sources at great depths and in obtaining a suitable quality of water for livestock and domestic use and for irrigation.

Any projections for the future of water resources in South Dakota must be in the realm of the statement—more water must be secured and stored. For the past several years the farm population in the State has been dropping at the rate of 1 to 2 percent per year. It may be expected that this trend will continue for a number of years to come; however, the introduction of large-scale irrigation may tend to reverse this trend. In the phase of agriculture in South Dakota, it is anticipated that the greatest need for additional water would be in the field of irrigation. Predictions are that by 1980, South Dakota's irrigated acreage may increase three to four times or to approximately one-half million acres. The need for more irrigation is quite evident as one of the great and eternal quests of man is for stability. The economy of a great portion of South Dakota has failed at various times to supply such needed stability. Research and studies have indicated that where large blocks of land are under irrigation, each irrigated acre tends to stabilize an additional 4 to 6 acres of dry land by assuring adequate feed supplies for livestock. The potential for irrigated acres in central and eastern South Dakota is tremendous. Principally this could be accomplished from water diverted from the Missouri River and from shallow ground-water supplies that could reach proportions of 2 to 3 million acres. Preliminary studies by the Bureau of Reclamation on the proposed irrigation of approximately one-half million acres have indicated that for many farmers in this area, it would be a definite economic asset to irrigate.

Studies by South Dakota State College on private pumping systems have indicated the same relationship.

Quite a number of other agricultural uses of water other than for irrigation purposes must be taken into account in the future of South Dakota. Even though the farm population is on a decrease at the present time, it is anticipated there will be a 50-percent increase in the use of water on the farms for all other purposes than for irrigation. Water use increase predictions are based on items such as:

Higher quality milk production;

Improved sanitation on the farm;

Use of labor saving devices which utilize water as a transporting agent;

More modern labor saving conveniences in the farm home;

Controlling the environmental conditions of livestock;

Improved livestock breeds to increase production.

In addition to the use of conventional methods of developing additional water supplies for the State, new techniques will aid in supplying future water requirements. Artificially recharging ground-water sources could conceivably store floodwater underground with a minimum, if any, evaporation loss. Ground-water resources are capable of yielding many times their present capacities if properly developed, coupled with a greater efficiency in their withdrawal. Artificially induced precipitation (weather modification) may revise local precipitation patterns. Research in the process of desalinization will yield methods to improve the quality of brackish water. New techniques and methods will tend to reduce evaporation and aid in the controlling of seepage. Improved water management and agronomic practices will provide greater efficiency in water utilization by plants. All of these new techniques and many more are needed in the projection of economic development of South Dakota. In the future, as in the past, unified combined cooperation, and effort of State, Federal, and local agencies, and South Dakota State College will look ahead for additional water supplies and as a result thereof a more stabilized agriculture for South Dakota.

The following table is a breakdown of figures of feed requirements for livestock in South Dakota for the year 1955 and also for the year 1959:

TABLE I.—*Feed requirements for livestock*

[In tons]

	1955	1959
Feed grains	2,600,000	3,000,000
Commercial byproducts	269,000	300,000
Hay and roughages	4,800,000	5,500,000

These following figures include feed both from the irrigated half million acres and also from dry-land farming. The reason for the lower figures in 1959 in comparison to 1955, which are included in crop reports, is due to the drought. In addition to these figures, in both the 1959 and possibly for the 1980 figures, carryover feed from previous years would be in addition to these figures.

TABLE II.—*Agricultural capacity to produce*

[In tons]

	1955	1959	1980
Feed grain	4,900,000	3,000,000	[1] 6,200,000
Hay and roughage	6,300,000	[2] 3,700,000	[1] 7,800,000

[1] Agricultural capacity in 1980 based on overall increase in production efficiency of over 20 percent over 1955 plus a total of ½ million acres under irrigation (an increase of 360,000 acres over 1959).

[2] Carryover.

TABLE III.—*Livestock numbers*

	1955	1959	1980
Cattle (all)	3,300,000	3,400,000	4,250,000
Sheep (all)	1,300,000	1,600,000	2,000,000
Pigs farrowed		2,900,000	3,625,000
Chicks hatched		14,000,000	17,500,000
Horses and mules		70,000	87,500

The above-listed figures for 1980 certainly must be taken as a projection; however, we feel that they are conservative as several items are in the picture during the next 20 years. For example, with the increase of concentrated farming in some of the irrigated areas, there could very easily be a major trend toward more feeding operations in the State in comparison to the number we have now, and consequently these additional acres taking up land for smaller farms could mean a decrease in the number of cattle under grazing conditions. As you will notice, comparing table II with table I, South Dakota had exactly the amount of feed grain produced in 1959 that was required, 3 million tons, but in the "Hay and roughage" category we produced less than what was needed, 3,700,000 versus 5,500,000 that was needed. This additional tonnage had to come from either carryover or from shipping in from other States.

We would also like to add one more table—the U.S. Department of Agriculture figures—which is as follows:

TABLE IV.—*Farm production needed to meet projected requirements in 1975*

	Percent change, 1955–75
Total farm output	27
All livestock and livestock products	33
All crops	22

These figures, of course, are for the overall United States and are just a little higher than our predictions for 1980, which makes us believe that we may be conservative in our estimates as the expansion for the change must be borne largely by the Midwest rather than many of the States along the eastern seacoast.

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Present status

As of September 1, 1959, South Dakota had 246 municipal public waterworks serving 238 of our 306 incorporated communities as well as 11 unincorporated towns. Federal and State public waterworks serving major military, institutional, educational, and recreational facilities number 27. We estimate that our 246 municipal waterworks serve almost 400,000 of the State's 700,000 population.

Of our municipal waterworks, 230 derive their supply from ground-water sources, 12 from surface sources, and 4 from a combination of ground-water and surface sources. All but two of the State and Federal waterworks use ground water; the exceptions are the intake structure and the powerhouse at Fort Randall Dam on the Missouri River.

The present types and numbers of water treatment works serving our 246 municipal systems are as follows: (1) Clarification, 7; (2) conventional softening, 9; (3) zeolite softening, 3; (4) iron and/or manganese removal, 21 plants serving 19 communities; (5) fluoridation, 7; (6) Defluoridation, 1; (7) chlorination only, 61.

The status of water treatment at our State and Federal facilities is as follows: (1) Clarification, 3; (2) zeolite softening, 2; (3) iron and manganese removal, 1; (4) chlorination only, 13; (5) electrodialysis, 1.

The bulletin "South Dakota Public Water Supply Data" dated March 1959 is attached for more detailed information on public waterworks.

Problems

On a statewide basis, public water problems were more widespread than usual during 1958 and became quite critical in certain areas during the recent hot summer. Our main problems can be summarized as follows:

1. Much of our population is either along the eastern border in the basins of the Big Sioux and James Rivers or in the Black Hills area. The Big Sioux and James River flows have been intermittent and the geology and topography of the rocky and mountainous Black Hills has always been a problem. Conversely, our most reliable fresh-water source is the Missouri River, which is located in the sparsely populated center of the State.

2. The unsatisfactory chemical quality of many of our ground-water sources, particularly the deep artesian formations, is a basic problem. Fortunately, from the standpoint of attracting industry, 18 of our 25 largest communities have a chemically acceptable supply of water. Many of our small towns cannot abandon surface sources or develop adequate ground-water sources until an effective and economical method for treatment of brackish water is readily available.

3. Conflicts or misunderstandings between water users representing family or farm domestic consumption, municipalities, irrigators, the livestock industry, and recreation interests.

4. South Dakota does not have available continuous and orderly basic water quality data for both surface- and ground-water sources in common use. There is a great need for long-range chemical, bacteriological, biological, physical, and radiological analyses of our public water sources.

Solutions

To furnish water users with an adequate supply of pure potable water, the problem must be approached from the total water resources picture—nationally, regionally, statewide, and locally. Towns and cities with water problems should engage consultants to study their needs for the next 20 or more years depending on the improvements needed.

Additional water supplies will have to be developed by artificial recharge of shallow ground water sources, impoundment of high flows which occur during periods of minimum use, transportation of impounded Missouri River water to our more populated areas and use of brackish ground water sources made potable by new water treatment methods.

Three brackish water treatment developments in South Dakota are felt to be of interest to this group. A permanent electrodialysis (electric membrane process) water treatment plant is now in place at the Gettysburg Air Force Station; the design features of this unit are similar to the field unit tested at Miller, S. Dak., in 1955. A 6-week field test of an improved electrodialysis unit was carried out at the Redfield State School and Home in July and August 1959. Finally, eight of our South Dakota communities have made formal application to the U.S. Department of Interior for consideration as the site of the Federal demonstration brackish water treatment plant to be located in the Northern Great Plains area.

Improved education of municipal officials, community leaders, the public and government is a must to improve our water works industry. It is interesting to follow promotion of a successful improvement program, and certainly disappointing to note the lack of promotion on some proposals which fail. Explanations regarding temporary water use restrictions point out the problems to the public and avoid unfair criticism. Public relations are a significant part of the entire program.

WATER POLLUTION CONTROL

Present status

Sewer systems are provided in 164 municipalities serving approximately 360,000 persons. The status of sewage treatment facilities as of June 1, 1959, in these municipalities is as follows:

Status	Number of cities	Percent	Population served	Percent
Satisfactory treatment	101	61.6	246,000	68.9
Additions or enlargements needed	31	18.9	59,000	16.7
Replace plant or new plant	32	19.5	51,800	14.5

Federal installations providing separate treatment for major facilities number 12. The remaining installations discharge wastes to municipal systems. Of the 12 treatment facilities noted, none are considered in need of major improvements at this time.

Only 5 major State installations provide separate waste treatment facilities and the remainder discharge wastes to municipal systems. Improvements will be completed within this fiscal year on two of these installations bringing all these treatment works to a satisfactory status.

Industrial wastes are predominantly treated in conjunction with municipal wastes. Private treatment facilities are operated by seven major industries, and improvements are needed in three of these installations. Partial treatment prior to routing wastes to municipal systems is provided by a majority of the larger industries. The bulletin entitled "Sewage Works in South Dakota, 1957" including an addendum for 1959 is attached for further information.

Problems

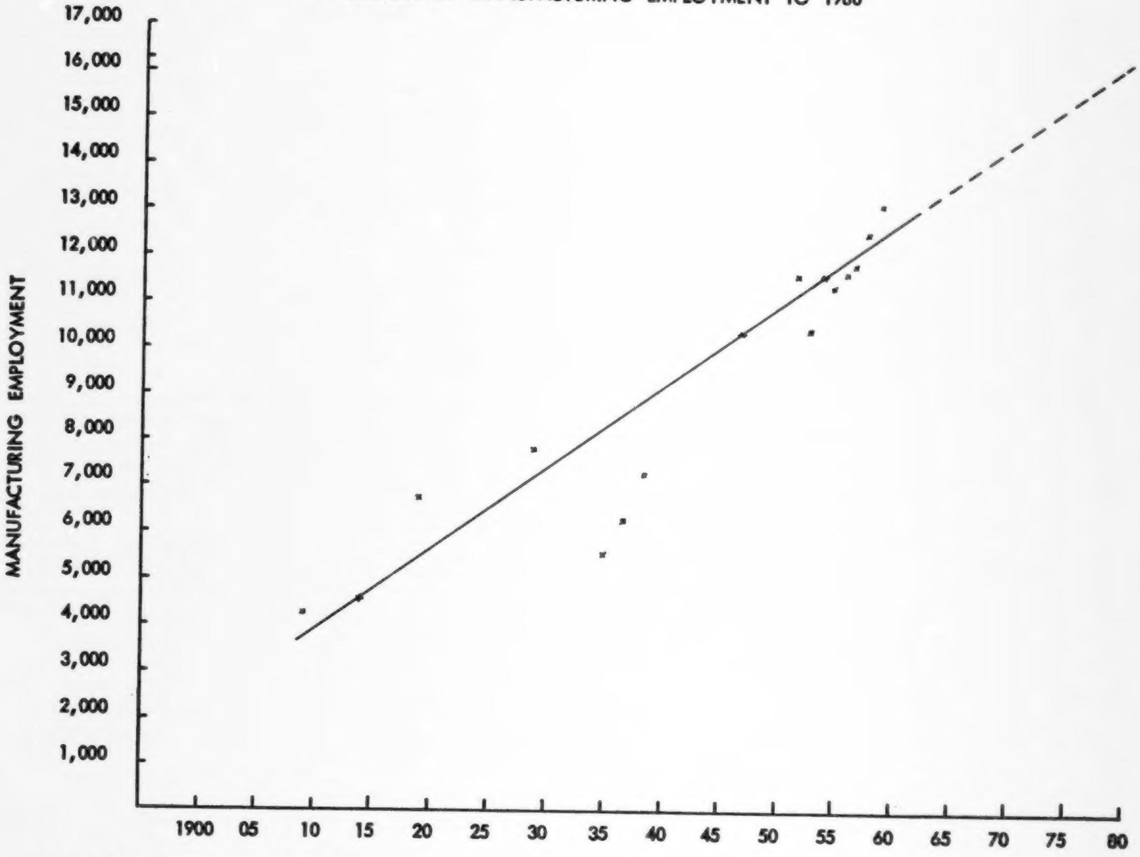
The major problems on water pollution control on a statewide basis are summarized as follows:

1. The lack of dilution water in a majority of the watercourses requires that a very high degree of waste treatment be provided.
2. Although adequate treatment is provided for a majority of the wastes prior to discharge, local problems exist in many areas.
3. Increased emphasis is needed to improve operation and maintenance of existing facilities.
4. Industrial development brings about new problems of a technical nature pointing out the need for expanded research programs in cooperation with private and governmental agencies.
5. A long range basic water quality data program is needed to obtain information on the chemical, physical, biological and radiological characteristics of the State watercourses.

Solutions

Protecting water resources through sewage and industrial waste treatment is a basic conservation measure. In recognition of these needs, Congress enacted the Federal Water Pollution Control Act which approaches the problem from several aspects. Statewide accomplishments in water

PROJECTION OF MANUFACTURING EMPLOYMENT TO 1980



South Dakota I.D.E.A. - Research Division
September 15, 1959

pollution control have been significantly enhanced through this legislation.

A continued and expanding program by the State water pollution control agencies will be necessary to keep pace with the expanding urban and industrial waste problems. Public education is an important phase of such programs.

The development of waste stabilization ponds in this area has brought about a very economical method of treatment. The use of this treatment method has significantly accelerated the water pollution program in this State. Additional research on this and other treatment methods can be expected to bring about further developments.

A statewide basic data program on water quality will be initiated contingent on budgetary resources.

SOUTH DAKOTA'S GROUND WATER NEEDS AND SUPPLIES

(By Allen F. Agnew, State geologist)

(Prepared by Merlin J. Tipton and Fred V. Steece, September 25, 1959)

INTRODUCTION

In 1955, South Dakota used an average of 243 million gallons of water per day, of which 76 percent or 185 million gallons was derived from ground water (MacKichan, 1957). This was the highest ratio of ground water use to total water use of any State. This means that South Dakota has had to rely heavily on wells for its water supply. It is this ground water supply with which the State geological survey is concerned, because a knowledge of the geology of the formations from which this ground water is obtained will be a tremendous aid in developing future water supplies in South Dakota.

The depths to this ground water and the formations from which it is obtained vary considerably in different parts of the State. There is a natural division between shallow and deep ground water, and between the eastern glaciated part of the State and the western nonglaciated part of the State (fig. 1).

SHALLOW GROUND WATER

Eastern South Dakota

That part of South Dakota east of the Missouri River is covered by glacial deposits which vary from a thin veneer to more than 700 feet thick; it is these glacial deposits that provide almost all of the shallow ground water in eastern South Dakota. The only other sources of shallow ground water in this part of the State are the recent alluvial deposits (table 1) along the major rivers and their tributaries, the ancient river channels buried beneath the glacial deposits, and the bedrock.

The shallow ground water obtained from the glacial deposits generally comes either from small sand lenses in the glacial debris, or from large sand and gravel plains called outwash deposits. The sand lenses do not provide large quantities of water, but most of them are capable of producing enough for individual farm needs. These sand lenses usually vary to such a degree that their size, shape, extent, and depth cannot be outlined accurately without drill hole or geophysical information.

The outwash plains, except where they are thin, provide large quantities of water, in many places enough to irrigate or enough for municipal supplies. These outwash plains occur at the surface and range up to 100 feet in thickness. In contrast to the sand lenses, they have a characteristic surface expression and therefore can be outlined very accurately. The State geological survey has mapped many such plains in several parts of eastern South Dakota in the past few years and has found them to have great potential value for future water development. The only outwash plain that has been exploited to any great degree as yet is the Parker-Centerville plain (Tipton, 1957) along the Vermillion River in Turner County (fig. 2), where more than 70 irrigation wells are now pumping (September 1959). However, there are many more undeveloped plains in South Dakota which contain enough water for irrigation, industrial, or municipal uses. These include the Big Sioux Valley plain (Steece, 1958; Lee, 1958) along the eastern border of South Dakota (fig. 2), the Missouri River plain, the Vermillion River plain from Turner County southward to the Missouri River plain; and several other outwash plains (fig. 2) not associated with major rivers. All of the outwash plains shown in figure 2 are large; not included are innumerable small ones, too small for the scale of the map. Most of the outwash plains shown in figure 2 have not as yet been investigated in detail, so their potential value is not accurately known. But, as an example, three that have already been mapped—the Parker-Centerville outwash, the Big Sioux Valley outwash, and the Missouri Valley outwash in the Yankton-North Sioux City area (Jorgensen, in press)—show a supply of approximately 2,000 billion gallons of water (enough to supply the whole State for 27 years at the rate of use during 1955).

Recent alluvium is also a source of shallow ground water in eastern South Dakota, but usually does not provide the quantities needed for more than individual farm wells. These alluvial deposits are found along rivers, streams, and creeks.

The buried channels of ancient (preglacial) rivers are another source of shallow ground water, and some of them could produce large quantities of water. However, these deposits have not yet been studied in detail in South Dakota; nevertheless, they should be included in any future water development program.

Bedrock, where it is close to the surface, is another source of shallow ground water in eastern South Dakota, but owing to the usually thick cover of glacial deposits, shallow water from this source has been developed in only a few places. The Sioux quartzite is locally used as a source of shallow water in Davison, Hanson, McCook, and Minnehaha Counties (fig. 2), although it does not provide large quantities. The Niobrara chalk also provides shallow ground water where it is near the surface in southeastern South Dakota (fig. 3b).

Western South Dakota

In general, shallow water supplies are difficult to obtain in western South Dakota, and are not a major source of water in that part of the State. The only shallow sources of water in western South Dakota are in alluvial plains and terraces and surface bedrock formations. Except along streams, the surface of western South Dakota is composed of bedrock, and about half of this bedrock is Pierre shale. The Pierre shale itself is not a good source of water and consequently most of the ground water in the Pierre shale area is derived from deep sources.

The alluvial plains and terraces along the major rivers and their tributaries provide enough water for individual farms and in places could produce larger quantities of water. They are such small areas that they do not constitute a major source of water in this part of the State.

Some bedrock formations, where composed of sand, provide good sources for shallow ground water. In the northwestern part of the State the Fox Hills sandstone (fig. 3a and table 1) provides a shallow source of good water, locally in large quantities (for areas mapped, see fig. 8). The Hell Creek formation (table 1) in this northwestern area has some sand zones which provide shallow water for farm use. The Tertiary sands in the south-central and southwestern part of the State (for areas mapped, see fig. 9) also provide good sources for shallow water. In the Black Hills area the bedrock limestones and sandstones, where near the surface, provide good sources of shallow water. Generally, however, alluvial sources are used for ground-water supplies, especially where the granite crops out in the central part of the hills (fig. 2).

Owing to the small amount of rainfall in the western part of the State, and to the limited supply from shallow sources, water is a very scarce and highly prized commodity which deserves the study of all agencies related to finding water supplies.

DEEP GROUND WATER

Deep ground water provides much of the water used in the State of South Dakota. Thousands of wells have been drilled into the artesian aquifers, especially the Dakota sandstones (Newcastle, Fall River, Lakota). Although these Dakota sandstones have lost much of their artesian head in the last 50 years, many places in the State still have flowing wells from this source. In addition, many other deeper formations also contain large quantities of untapped water.

Any future water development should include a conservation program of plugging the wild flowing artesian wells. These wild wells have reduced the piezometric (pressure) head of the flows tremendously since the artesian formations were first tapped. As an example, the artesian pressure at Woonsocket dropped from 250 pounds per square inch in 1890 to less than 25 pounds in 1950. The plugging of the wild wells will greatly curtail this rapid decrease in pressure, and will stop a needless waste of water.

The chief potential sources of deep ground water in South Dakota are:

1. Fox Hills formation (fig. 3a): sand and sandy clay; up to 250 feet thick.
2. Niobrara formation (fig. 3b): chalk and marl; becomes sandy westward; about 200 feet thick in central part of the State, 120 feet thick in the east, and 400 feet thick in the west.
3. Codell sand of Carlile formation (fig. 4a): Carlile shale includes the 50-foot thick Codell sand in parts of southeastern South Dakota.
4. Newcastle sand of Graneros formation (fig. 4b): Graneros shale includes the lensing Newcastle sand (up to 100 feet thick) in the western part of the State.
5. Fall River-Lakota sequence (fig. 5a): interbedded sands and shales; up to 400 feet thick; several productive sands.
6. Morrison-Sundance (fig. 5b): Morrison formation is mostly shale with numerous interbedded sands; Sundance formation is chiefly sand, up to 500 feet in thickness. Several sands are water bearing in Black Hills area. Sundance artesian sand is productive in central South Dakota.
7. Minnelusa formation (fig. 6a): mostly limestone and dolomite with interbedded shale and sandstone; up to 500 feet thick; several productive zones.
8. Madison formation (fig. 6b): chiefly limestone and dolomite up to 900 feet thick; several productive zones.
9. Ordovician-Cambrian (fig. 7a): Ordovician Red River limestone and dolomite, Winnipeg sandstone, and Cambrian Deadwood santstone in northwestern half of State; Lower Paleozoic sandstones in southeastern corner of State.
10. Precambrian (fig. 7b): Sioux formation: massive silica cemented hard quartzite and thin interbedded "shales." Water occurs in highly jointed and fractured areas.

Of the rock units discussed above, several have been important sources of water over the years, although most of them contain highly mineralized water. Probably the most important and best known of these is the Dakota sandstone series; nearly all the deep artesian wells in the State have their sources in these sandstones. Second in importance is the Fox Hills formation especially where it is at or near the surface. The Fox Hills yields adequate supplies of high quality water both for domestic and industrial use. The Codell sand is an important source of relatively shallow artesian water of good quality in southeastern South Dakota. The Sundance and Minnelussa formation also provide large volumes of water that is rather high in mineral content, in both central South Dakota and the Black Hills area.

Waters from the other rock units discussed are also likely to be high in mineral content.

FUTURE DEVELOPMENT

The plans for the South Dakota State Geological Survey in the next 20 years call for a large amount of geologic mapping of ground water resources. Many sources of ground water in South Dakota have not yet been studied either geologically or hydrologically, and it is the plan of this department to study as many of these sources as budgetary limitations will permit.

Certain glacial deposits in the eastern South Dakota area are good water sources and need to be studied further, as they have the potential to provide much of the future water needed in this part of the State. The western part of the State badly needs an up-to-date artesian water study much like those that have been carried out recently in the eastern part of South Dakota by the State geological survey (Barkley, 1952 and 1953; Erickson, 1954 and 1955).

In addition to the general studies referred to above, many of the water supply problems in South Dakota are local in nature and must be studied individually, because of the locally different and complex problems involved.

It has been shown that water problems already exist in South Dakota, and undoubtedly will become more acute in the future. Most of these problems will be readily solved by a proper study of the geology and hydrology of the ground water resources. Agencies such as the State geological survey should have substantially increased budgets so that they can devote increased effort to the study of their specific phases of the program.

If this accelerated program of study is carried out, most of the immediate water needs of South Dakota will be provided for, and many of the future water problems will be solved.

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Table 1. Stratigraphic Systems Present in South Dakota

Time Rock Chart

Group	System	Formation or Rock Type
Cenozoic	Recent	Alluvium
	Quaternary	Glacial stream and wind deposits
	Tertiary	Sands, silts, clays
Mesozoic	Cretaceous	Hell Creek
		Fox Hills
		Pierre
		Niobrara
		Carlile
		Greenhorn
		Graneros
		Fall River
		Fuson
		Lakota
	Jurrassic	Morrison
		Sundance
Paleozoic	Pennsylvanian	Minnelusa
	Mississippian	Madison
	Devonian	Limestones & dolomites
	Silurian	Limestones & dolomites
	Ordovician	Limestone & dolomites
	Cambrian	Sandstone & shale
Precambrian	Precambrian	Sioux quartzite and granite

FIGURE 1

SOUTH DAKOTA

COUNTY OUTLINE MAP

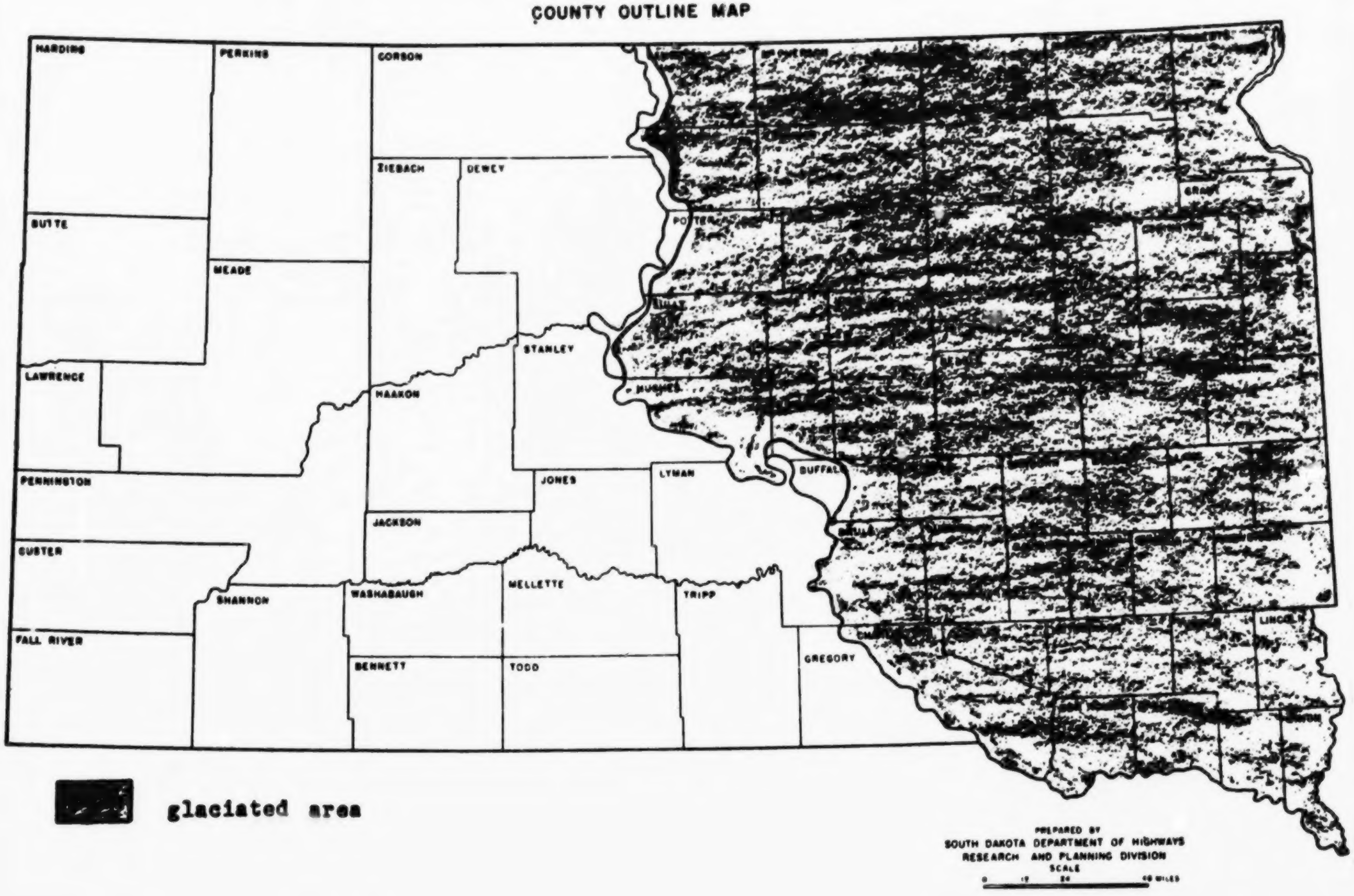

HARDING
PERKINS
CORSON
ZIEBACH
DEWEY
BUTTE
MEADE
LAWRENCE
STANLEY
HAAKON
POTTER
HUGHES
PENNINGTON
JONES
LYMAN
BUFFALO
JACKSON
CUSTER
SHANNON
WASHABAUGH
MELLETTE
TRIPP
FALL RIVER
BENNETT
TODD
GREGORY
LINCOLN
glaciated area
PREPARED BY
SOUTH DAKOTA DEPARTMENT OF HIGHWAYS
RESEARCH AND PLANNING DIVISION
SCALE
0
12
24
48 MILES

FIGURE 2—SHALLOW WATER

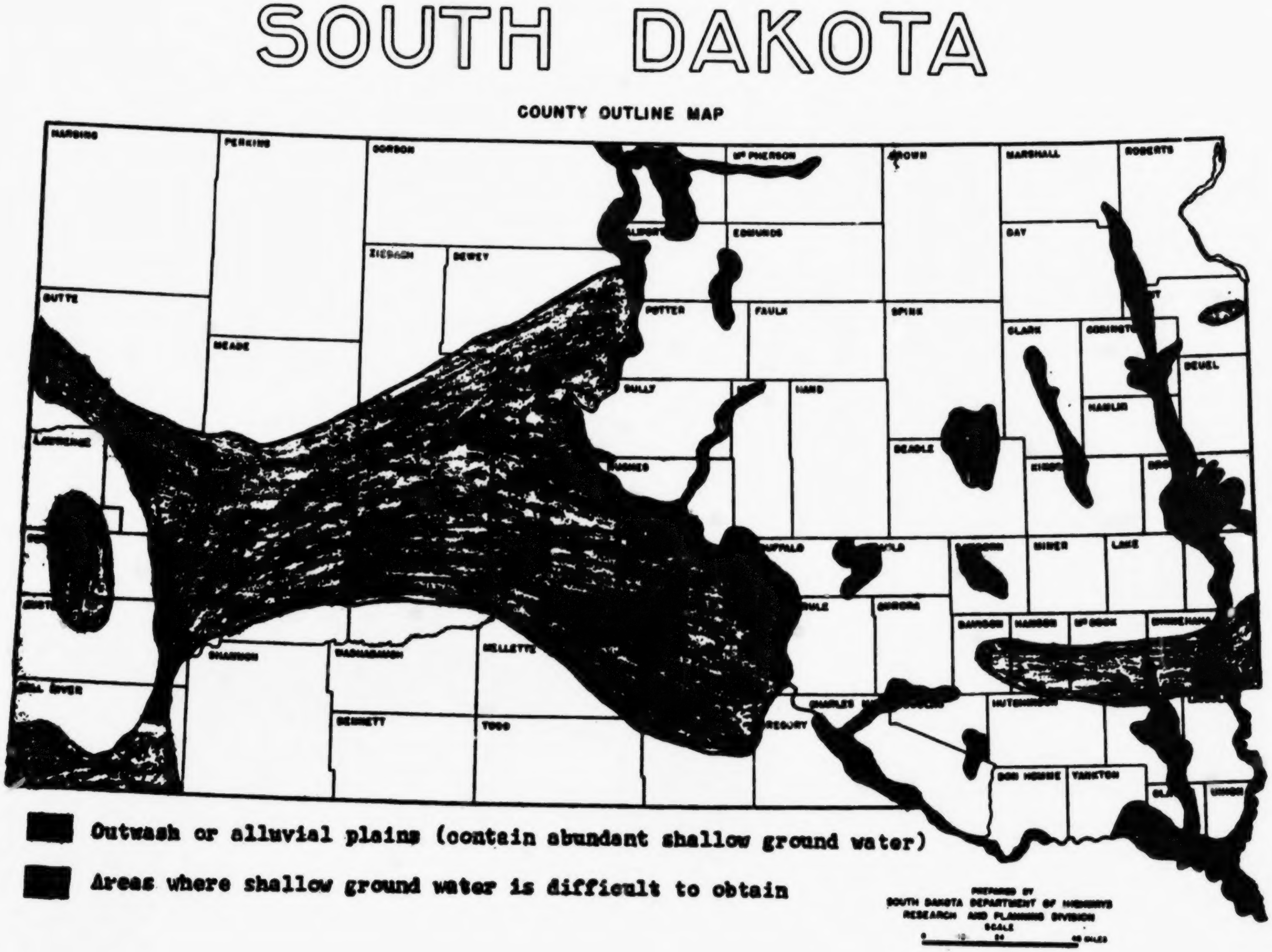
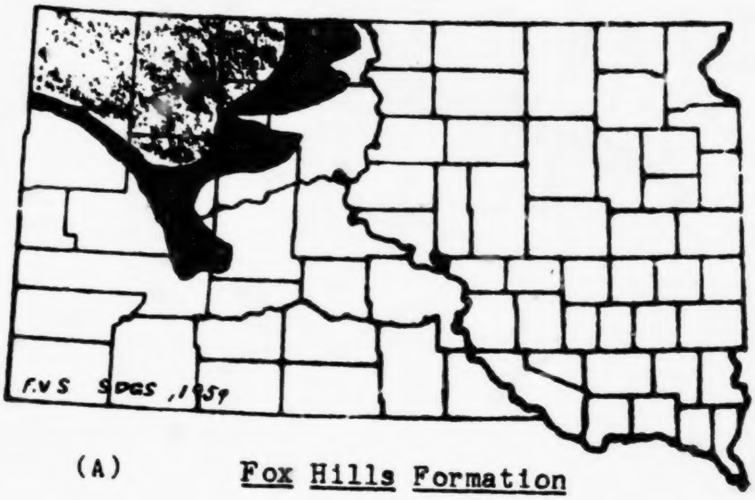

SOUTH DAKOTA
COUNTY OUTLINE MAP
HARDING
PERKINS
CORSON
McPHERSON
BROWN
MARSHALL
ROBERTS
ALBERT
EDMUNDS
DAY
ZIEBACH
DEWEY
BUTTE
POTTER
FAULK
SPINK
CLARK
CODINGTON
DEUEL
MEADE
SULLY
HAND
HAMLIN
LAWRENCE
HUGHES
BEADLE
KINGSBURY
BUFFALO
JERAULD
SANBORN
MINER
LAKE
AURORA
DAVISON
HANSON
McCOOK
MINNEHAHA
SHANNON
WASHABAUGH
MELLETTE
FALL RIVER
BENNETT
TODD
GREGORY
CHARLES MIX
HUTCHINSON
BON HOMME
YANKTON
UNION
■ Outwash or alluvial plains (contain abundant shallow ground water)
■ Areas where shallow ground water is difficult to obtain
PREPARED BY
SOUTH DAKOTA DEPARTMENT OF HIGHWAYS
RESEARCH AND PLANNING DIVISION
SCALE
0
12
24
48 MILES

FIGURE 3

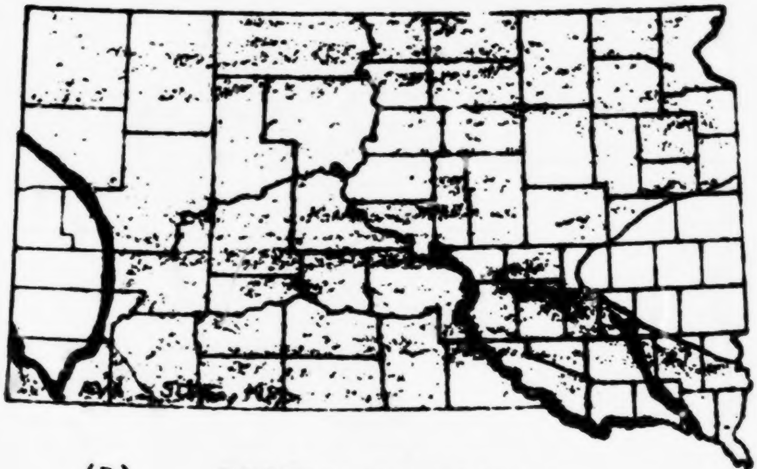


(A) Fox Hills Formation

(chiefly sand)

■ outcrop

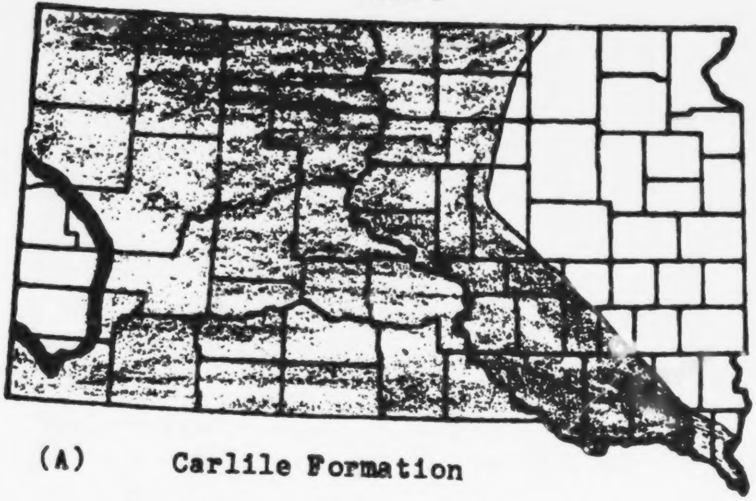
▨ subsurface distribution



(B) Niobrara Formation

(chalk, marl, limestone)

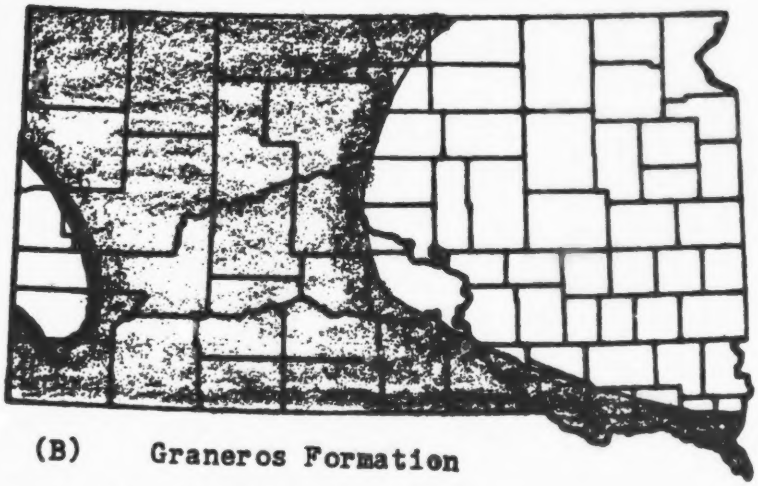
FIGURE 4



(A) Carlile Formation (includes Codell sand)

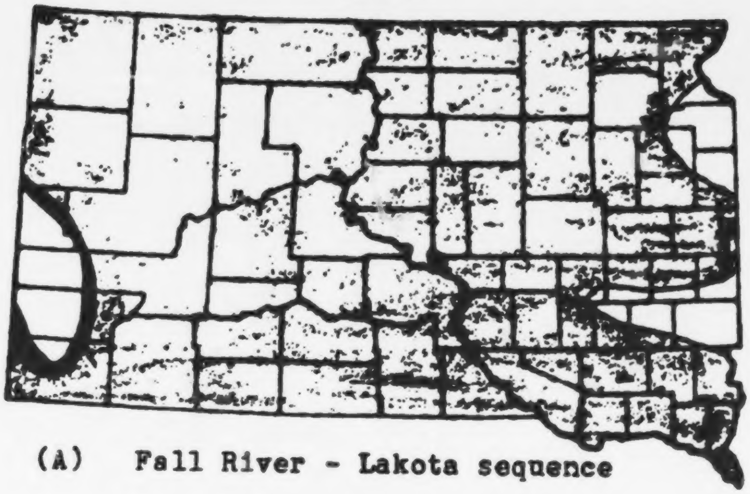
■ outcrop

▨ subsurface distribution



(B) Graneros Formation (includes Newcastle sand)

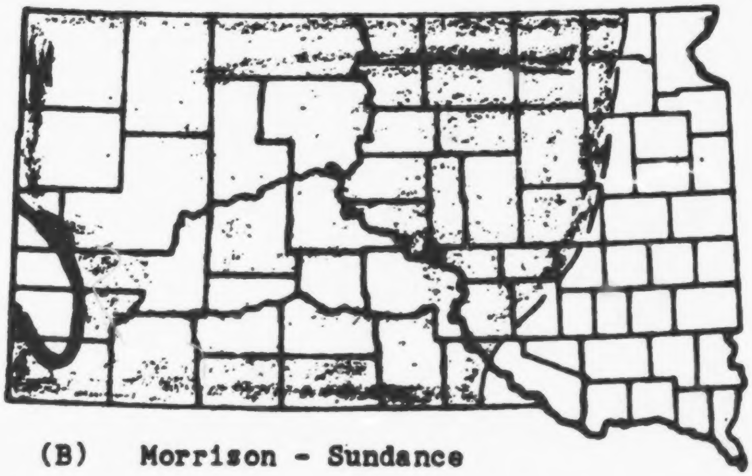
FIGURE 5



(A) Fall River - Lakota sequence
(chiefly sand)

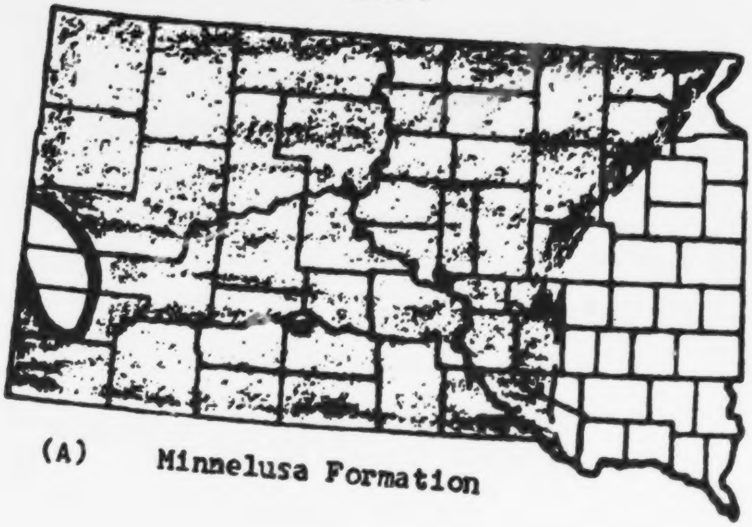
■ outcrop

▨ subsurface distribution



(B) Morrison - Sundance
(chiefly shales with sands)

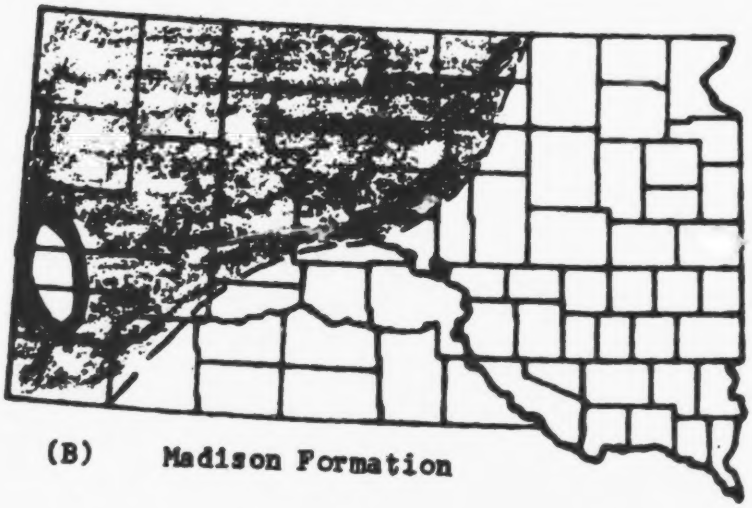
FIGURE 6



(A) Minnelusa Formation

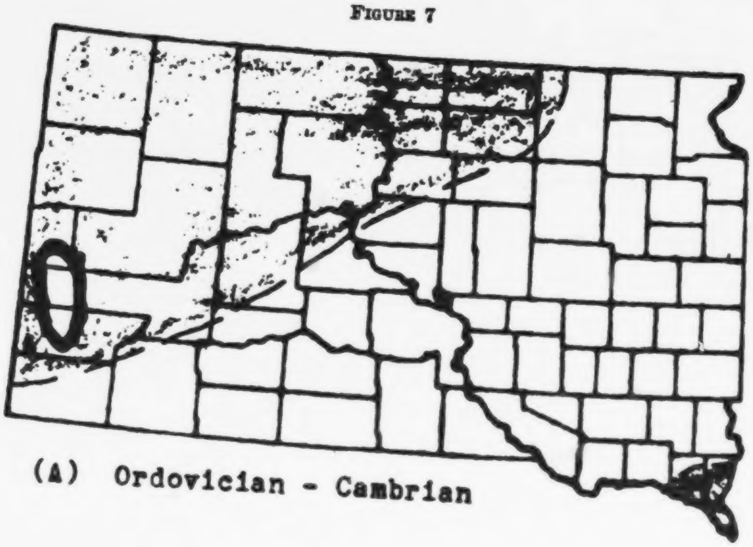
■ outcrop

▨ subsurface distribution



(B) Madison Formation

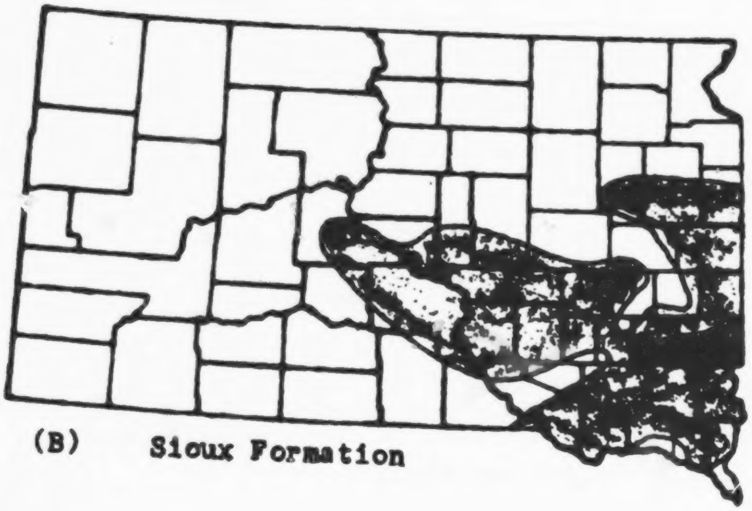
FIGURE 7



(A) Ordovician - Cambrian

■ outcrop

▨ subsurface distribution



(B) Sioux Formation

FIGURE 8

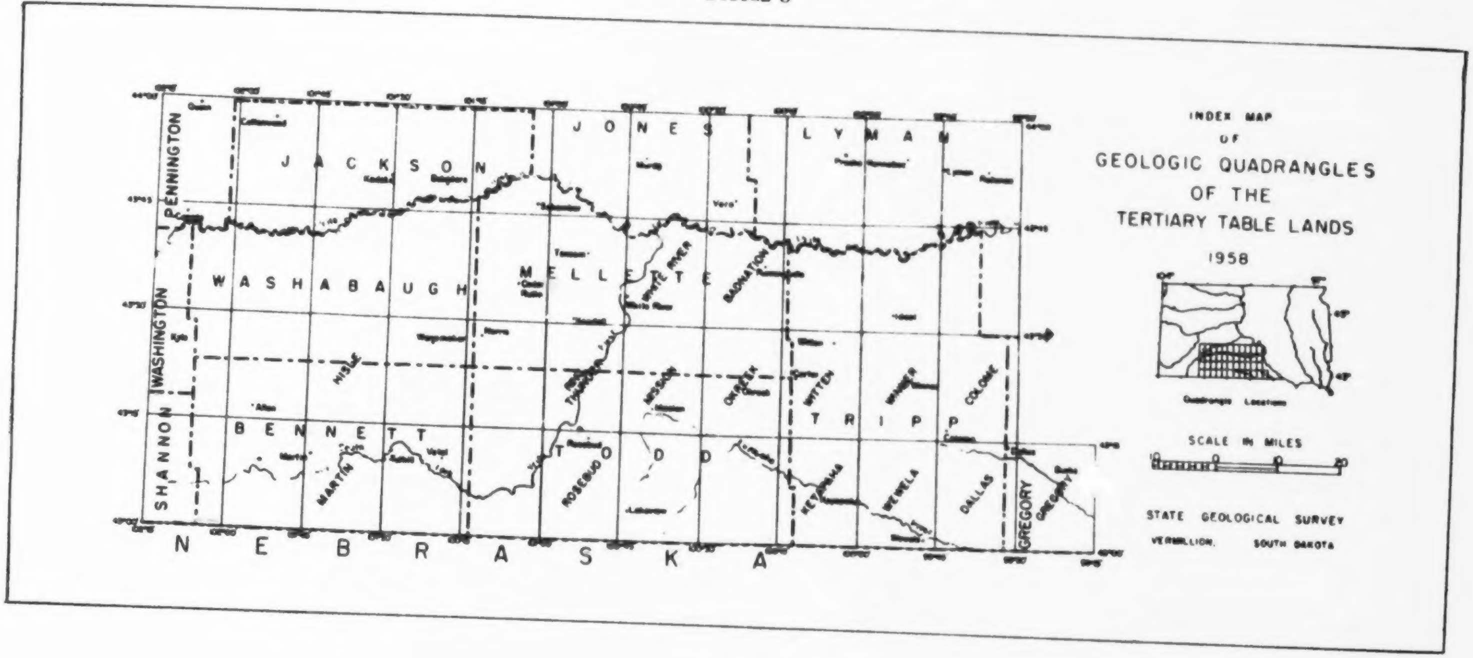
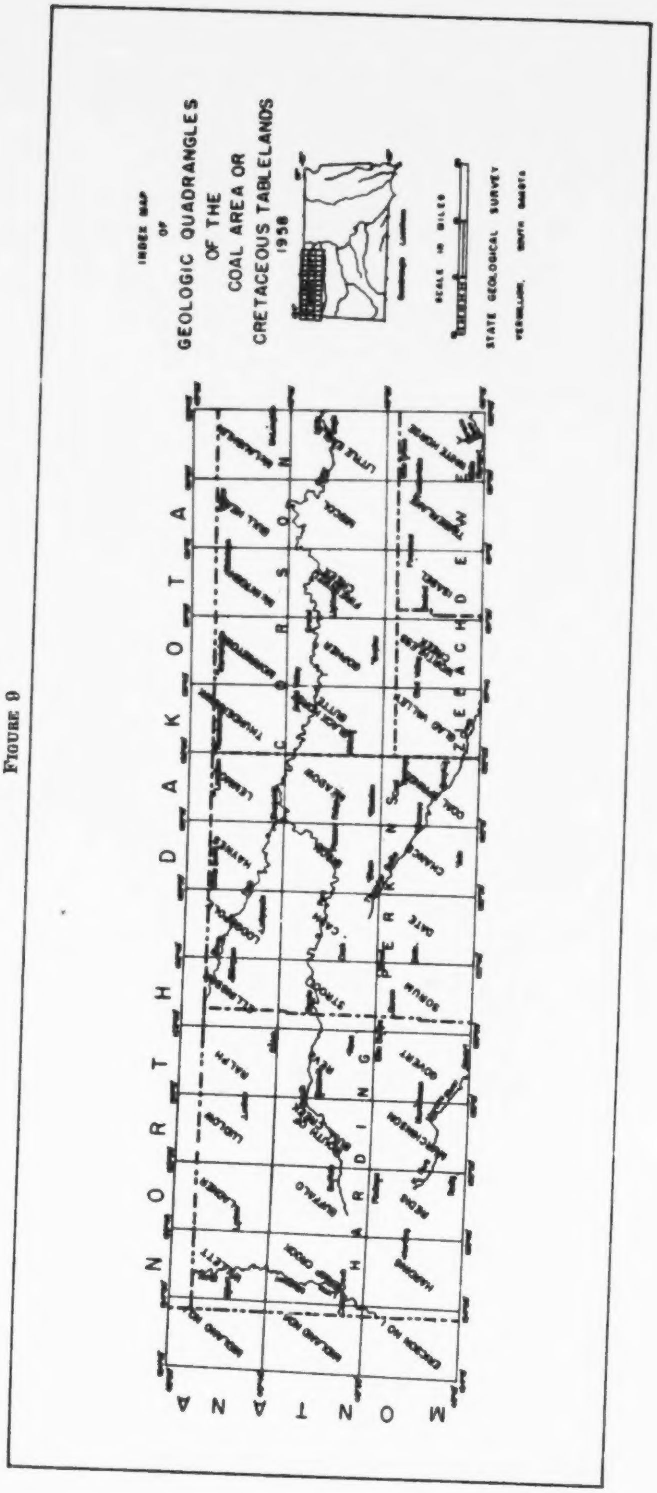

INDEX MAP
OF
GEOLOGIC QUADRANGLES
OF THE
TERTIARY TABLE LANDS
1958
Quadrangle Locations
SCALE IN MILES
10
0
10
20
STATE GEOLOGICAL SURVEY
VERMILLION, SOUTH DAKOTA
PENNINGTON
WASHINGTON
SHANNON
JACKSON
JONES
LYMAN
WASHABAUGH
MELLETTE
BENNETT
TODD
TRIPP
GREGORY
NEBRASKA
WHITE RIVER
BADNATION
HISLE
MARTIN
ROSEBUD
MISSION
OKREEK
WITTEN
COLOME
DALLAS
WEWELA
KEYAPAHA
GREGORY

FIGURE 9


INDEX MAP
OF
GEOLOGIC QUADRANGLES
OF THE
COAL AREA OR
CRETACEOUS TABLELANDS
1958
SCALE IN MILES
STATE GEOLOGICAL SURVEY
VERMILLION, SOUTH DAKOTA
NORTH DAKOTA
MONTANA
HARDING
PERKINS
CORSON
ZIEBACH
DEWEY
RALPH
BUFFALO
SORUM
DATE
LITTLE EAGLE

TENNESSEE

State of Tennessee,
Department of Conservation and Commerce,
Division of Water Resources,
Nashville, Tenn., October 14, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: On June 29, 1959 Governor Ellington acknowledged your letter of June 23, 1959, sent you a copy of, "Public Water Policy in Tennessee, 1956," and requested that you be furnished with a brief statement as to the water problems in Tennessee. I hope that you will find the information attached useful.

Yours truly,

Raleigh W. Robinson, *Water Engineer.*

Summary of Water Problems in Tennessee

Most of Tennessee has an average rainfall of over 50 inches. However, much of this precipitation occurs during the winter months. The summer and early fall are dry seasons for most of Tennessee. It is during this period that many uses are at a maximum.

Many of the rivers in Tennessee have large rates of flow throughout the year. However, on some of these riverflows are so reduced at times that actual shortages and conflicts over use have appeared and development has thereby suffered. Most land in the State lies on small streams. As to regions in the State, small streams have fairly dependable flows in most of east and west Tennessee and in some parts of the Highland Rim. In the central part of the State and on the Cumberland Plateau the flow of small streams is critically low at frequent intervals. Streams draining up to 100 square miles have ceased to flow at times. Without storage dams or other measures, the economic development of much of this critical area will be severely restricted. Additional hydrologic data is needed as to small streams.

The ground water resources of the State are quite variable. Along the western fringe of the Great Smoky Mountains, in the valley of east Tennessee, and in the Highland Rim there are modest ground-water supplies averaging 10 to 25 gallons per minute, and in a few areas yields of better than 100 gallons per minute are possible. Along the Cumberland Plateau and in the central basin the ground-water supply is the poorest in the State, the yield averaging from 1 to 5 gallons per minute. Sufficient quantities of water for industries and towns are difficult to find. In west Tennessee large quantities of ground water are generally available, yields in excess of 500 gallons per minute are not uncommon. At Memphis withdrawals exceed 130 million gallons per day, and the city alone uses over 50 million gallons. Widespread studies need to be made of the groundwater resources of the State.

The average withdrawal of water for all purposes from ground and surface water sources in Tennessee is approximately 6,500 million gallons per day. Agricultural irrigation is a new and important user of water. There are 1,021 irrigation systems of record in the State. In 1959, the rainfall was so distributed that little water was needed for irrigation. On some days in previous years the withdrawals of water for irrigation exceeded the total pumpage of all public water supply systems in the State. Most of the increased use of water in recent years has been industrial. Sixty percent of the withdrawals in the State are for steampower generation. Manufacturing use is about 30 percent of the total. Municipal and domestic uses of water account for only 5 percent of all withdrawals in Tennessee. Under the Tennessee Valley system there are 14 major reservoirs and 800 miles of navigable waters in the State. On the Cumberland River and its tributaries there are five major reservoirs and more than 200 miles of navigable waters.

In many areas of Tennessee erosion and sedimentation are a major problem. Considerable upstream stabilization of soils is needed. A number of the towns and cities of the State have flood control problems. There are 272 public water systems in the State serving 68 percent of the total State population. Many of these systems are in need of major improvements. Of the 192 sewer systems in the State, 111 are considered satisfactory. Additional improvements are needed in several areas of the State. Much additional hydrologic information is needed with reference to the ground and surface water resources of the State.

Only in west Tennessee could the ground-water resource be considered to be satisfactory or reliable. The valley of east Tennessee has the next best supply. In middle Tennessee the yield averages from 1 to 5 gallons per minute. Many wells afford no water.

Over the State the low flows of streams are frequently unsatisfactory for the dilution of wastes over much of the year. Tennessee is constructing an average of one sewage disposal plant each month and is keeping up with the demand. Plants are designed for a growth of 20 years. Additional forces are needed in order to properly observe the pollution of the streams of the State.

In 1950, Tennessee had a population of 3,292,000. The 1970 estimate is a population of 4,088,000 an increase of 24 percent.

For the grand divisions of the State the 1959 population was:

Western Tennessee (22 counties) 984,700, to increase 32 percent by 1970.

Middle Tennessee (40 counties) 1,023,500, to increase 14 percent by 1970.

Eastern Tennessee (33 counties) 1,283,500, to increase 26 percent by 1970.

For additional information please refer to, "Public Water Policy in Tennessee, 1956."

TEXAS

EXECUTIVE DEPARTMENT,
Austin, Tex., November 20, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: In compliance with your request, I herewith transmit the report of the State of Texas on water resources, which has been prepared in cooperation with the Texas Board of Water Engineers. Under separate cover I am also forwarding other materials which may be helpful to your study.

Thanks to you and your committee for this opportunity to express our views. You may be sure of our cooperation in every way possible.

Kindest personal regards.

Sincerely yours,

PRICE DANIEL.

REPORT OF STATE OF TEXAS

TO THE SENATE SELECT COMMITTEE ON WATER RESOURCES

I. STATEMENT OF THE EXISTING SITUATION AND PRESENT TRENDS

A. Summary of water resources available

The statement has been made that the water resources of Texas are adequate to satisfy Texas' needs if they are properly developed and distributed. That statement is correct, but the overall situation should be understood with respect to occurrence, distribution, and quality of both the surface and the ground waters of the State.

Since rainfall and other forms of precipitation are the original sources of runoff and underground percolating waters, excepting such deposits as may have been left over from geologic times, it is well to note that the average annual rainfall in Texas varies on a descending scale from east to west from an average annual rate of about 55 inches in the Beaumont-Port Arthur area of east Texas to about 8½ inches at El Paso in the trans-Pecos area. This gives an average decrease in rainfall of approximately 1 inch per 17 miles along the line connecting the two areas. This maldistribution, expressed in terms of average annual rainfall, is further aggravated by the wide extremes in climatic conditions that range from prolonged droughts to periods of heavy runoffs that produce devastating floods.

The drought which ended in 1957 had seriously affected almost every county in this State and, ironically as it might seem, was broken by excessive rainfall over wide areas and for prolonged periods, resulting in practically all of the intrastate and some interstate rivers and streams discharging floodwaters at near record peaks for approximately 3 months. These widely varying extremes in climate, as well as weather, have a direct influence upon all surface water supplies of the State and on ground water aquifers subject to recharge. Severe droughts caused by insufficient precipitation, coupled with high rates of evaporation, are characteristic of most of the country west of the 98th meridian and was included in the section lying west of the "zero line" of the drought report prepared under the direction of the Special Assistant to the President for Public Works Planning in October 1958. In addition to this being a water-deficient area, natural mineral pollution reduces the quality of much of the water to a point to make it unusable for municipal, agricultural and industrial purposes in some sections. This heavy mineralization is largely concentrated in the upper portions of the Red and Brazos River Basins, but causes deterioration in quality for the entire reaches of the Brazos, and on the Red it extends down to and includes Lake Texoma.

The geology of the State controls major ground water aquifers, adversely affecting uniform distribution. These water-bearing formations are found in somewhat of an erratic pattern as to occurrence, quantity, and quality, and when this condition is coupled with the fact that the surface waters of the rivers and streams have intermittent flow characteristics, it becomes more readily understandable why there is no one water problem in Texas, but, instead, there are a great number of water problems. Because of the geology and intermittent characteristics of the streams and rivers, it is also understandable why many of the water problems have to be considered, and sometimes solved, on a purely local basis. Conversely, the solution of each problem, and particularly if it involves the construction of a reservoir, must be recognized as having an influence on other projects on the stream and particularly the effect on downstream water rights. The general pattern of water development in Texas has been on a project-to-project basis, satisfying needs as they develop, and this has not furnished much opportunity for coordinated planning to prevent overlapping interferences leading to a waste of water resources, both from the standpoint of under as well as over development or improper location of projects. The history of developments in the State, including Federal programs, shows that it has followed a hit-and-miss pattern, and that is why this administration inaugurated in 1957 a statewide water planning program and has urged better coordination between Federal and State interests and agencies. Gov. Price Daniel and the State board of water engineers have urged this as the only means for orderly and coordinated development.

The topography of Texas incorporates several unusual features that contribute an influence on water problems. The State is drained largely by its own river systems which generally flow from northwest to southeast. All rivers, including the border streams, discharge into the Gulf of Mexico, but several of them traverse long distances in terms of river miles before they meet the gulf. In the Panhandle section, generally referred to as the High Plains of Texas, elevations range up to 3,000 to 4,000 feet, and if a southwesterly line is followed into the mountainous section of the trans-Pecos area, the elevations encountered would be generally of the order of from 3,500 to 8,000 feet, except for the Pecos Valley which varies downward from 2,500 feet. High elevations in a generally short area introduces the problem of pumping and transportation costs if imports are to be made from areas of surplus water which have elevations of less than 400 feet. But all is not bad as a result of topographic and geologic conditions, because these combine to give Texas a drainage system, which for all practical purposes originates and ends within the borders of the State. The Neches-Angelina, the San Jacinto, the Trinity, the Brazos, the Colorado, the Guadalupe-Blanco, the San Antonio, the Nueces, together with a lot of coastal streams are contained in the State from origin to point of discharge. The boundary streams—the Rio Grande, the Red and the Sabine Rivers—are of concern to other States and so are the Pecos and Canadian which originate in New Mexico. The Canadian crosses the Panhandle of Texas and joins the Arkansas River in Oklahoma. Interstate compacts have been made for the Rio Grande, Pecos, Canadian, and Sabine, and one is in the negotiating stage for the Red.

Texas is in the fortunate position of being officially recognized as owning its surface waters. Senate Document III, 85th Congress, 2d session, entitled "Water Developments and Potentialities of the State of Texas," a joint report prepared by the Texas Board of Water Engineers, Corps of Engineers, Soil Conservation Service and the Bureau of Reclamation, recognizes Texas' primary responsibility for developing and maintaining an overall water program for the State. That document states that "Actual construction, operation, or use of projects affecting the waters of Texas may be accomplished by local or Federal agencies, but all investigations, reports, and plans for such *development, operation, and use necessarily must, in the interest of coordination, be conducted in cooperation with and under the leadership of the board of water engineers on behalf of the State which owns the waters, and determines the use to which the waters will be put.*" [Emphasis supplied.]

That document, in addition to recognizing ownership by the State of its waters subscribes to the soundness of the policy that provides for the administration of the water resources by the State. In section VII, pages 165 and 166, we find the following:

> The Congress has recognized the peculiar value of the systems of water rights that have developed in Western States such as Texas, and has plainly announced its desire

that these systems be preserved and protected. Express congressional authority is a condition precedent to the exercise of any right by Federal agencies. Unlike State agencies, they have no general and continuing responsibility of their own for initiating and carrying into effect systems of watershed development and control. They construct dams and reservoirs, and the congressional authorizations which direct them in these projects are based on cooperative planning by both Federal and State agencies. However, basic responsibility for planning leadership rests with and must be exercised by the State. In this manner, the combined resources of both State and Federal Governments are most efficiently coordinated in the accomplishment of a goal desired by both; namely, orderly development without duplication of effort, and assurance against overlapping of planning and interference of projects.

Title to the waters of the ordinary flow and underflow of the rivers and streams of Texas, and the storm, flood, and rainwaters of every river, stream, and watershed in Texas, is held in an active trust for the benefit of the people of Texas by the constitutional and statutory agencies of this State charged with the responsibility of conserving and developing this vital natural resource. The people of Texas have a right to expect these State agencies to discharge fully the responsibility placed on them of controlling, storing, preserving, and distributing this water for all useful purposes; and these agencies have the primary and continuing obligation to accomplish all things necessary to a satisfaction of this charge on them. In fulfillment of this obligation, the legislature in 1913 created the board of water engineers and charged it with the responsibility of administration of the State's waters. Statutory and constitutional enactments since then clearly reflect the intention and judgment of the people and the legislature that the public interest of Texas in its waters should be administered by the board of water engineers under legislative standards. In order to discharge these responsibilities, the board has to maintain an inventory of the State's waters and authorized diversions, as well as coordinate and assist in the planning of projects at the local level while still developing and maintaining an overall water program for the State as a whole.

In line with recognized State policy, the legislature has also delegated the responsibility for the actual development of water resources to the lowest possible governmental level capable of performing the desired functions. Thus it is, as it has been in the past, the responsibility of local interests to recognize the needs of their area and initiate action toward the satisfaction of these needs. The board of water engineers, as a part of its responsibilities, is qualified to aid in this process.

Although the State policy is previously outlined, it has also been recognized by the legislature that all of the local water needs are an integral part of a larger one. Therefore, it has created the conservation and reclamation districts, some of which have been entitled river authorities, which have been charged with the responsibility under the general supervision of the board of water engineers of coordinating and planning for maximum utilization of the water resources in their respective river basins or portions thereof. This is accomplished through the preparation of master plans which must be approved by the board of water engineers; however, the Governor has designated the State soil conservation board as the agency to approve or disapprove projects provided for under the Watershed Protection and Flood Prevention Act (Public Law 566, as amended).

Pursuant to the legislative provisions for the development of master plans by the conservation and reclamation districts and the river authorities, the board of water engineers has received and approved five master plans for basin developments and has before it two additional basin plans. The river authorities have been most diligent in pursuing their responsibilities and have made studies and investigations which have pinpointed many of the water problems, together with recommended solutions, and have laid the foundation for the development of projects well ahead of the present needs for the water. Approval of these master plans does not freeze a pattern of development, because as economic conditions change and population patterns shift it will be necessary to revise the plans.

In order to more clearly present the topographic and geologic and hydrologic features of the drainage systems, together with the underground reservoirs, an appendix consisting of seven maps is made a part of this report. Plate No. 1 presents the average annual rainfall for Texas. Plate No. 2 shows the zones of runoff in Texas. Plate No. 3 shows river basins and storage reservoirs of 5,000 acre-feet and over and the proposed storage reservoirs of 5,000 acre-feet or more. The proposals include authorized Federal projects. Plate No. 4 shows areas supplied by principal water-bearing formations in Texas. Plates No. 5 and No. 6 show in graphic form, supplemented by river discharge totals, the wide variations between runoff for a typical drought year as compared to a year of heavy rainfall. Plate No. 7 purports to show the general conditions of water quality in Texas streams and rivers.

The present situation as to availability of water is perhaps best pictured by listing the storage capacities of surface water reservoirs by river basins and separating the space provided for conservation storage in each basin. The following table is such a presentation.

TABLE I.—*Surface water storage reservoirs (both Federal and non-Federal) over 5,000 acre-feet in operation Jan. 1, 1958 (dependable yields are not available)*

Watershed	Conservation capacity	Total capacity
1. Candian	12,100	12,100
2. Red	1,286,570	2,619,600
3. Sulphur	145,300	2,654,300
4. Cypress	275,604	867,500
5. Sabine	57,650	69,350
6. Neches	165,060	194,760
7. Trinity	1,457,630	2,831,480
8. San Jacinto	172,525	584,025
9. Brazos	1,338,039	4,283,289
10. Colorado	2,757,384	3,976,344
11. Lavaca	0	0
12. Guadalupe	18,450	18,450
13. San Antonio	254,970	275,250
14. Nueces	300,000	300,000
15. Rio Grande	1,584,708	2,751,988
16. Coastal	18,626	18,626
17. Rio Grande drainage	32,843	32,843
Total for State	9,877,459	21,489,905

(The column marked "Conservation capacity" in table I includes water stored for hydroelectric use, and the column entitled "Total capacity" includes conservation storage, dead storage, sediment storage and flood control storage. The total capacity on Red River does not include the estimated portion allocated in Texhoma for runoff from Oklahoma; Falcon Reservoir on the Rio Grande is allocated on the basis that the waters are divided by treaty.)

During the drought period it was suggested and is now emphasized that flood storage be reevaluated in some of the Federal reservoirs in the interest of increasing the conservation storage.

B. Statement on withdrawal and use of water

Conservation storage and total storage space in surface reservoirs of over 5,000 acre-feet is presented above, and in response to the request for information on water use, two tables are offered: Table II—Use of surface waters and Table III—Use of ground waters.

In table II some of the uses listed under "Consumptive" are only partially so; for example, return flows through sewage treatment plants under municipal use, and industrial processes where the water is used for cooling purposes only and returned to the stream with no loss except the induced latent heat load in the water discharge to the stream. Industrial water use is permitted for direct diversions from streams without utilization of evaporative-type units, as well as diversions for storage and recirculation through evaporative-type units for cooling purposes. Irrigation waters have a variable and indeterminate amount of return flow to the streams, depending upon local conditions.

TABLE II.—*Reported use of surface water (in acre-feet) in Texas by basins during 1957*

Basin	Consumptive		Nonconsumptive
	Municipal, mining, and industrial	Irrigation	
1. Canadian	----------	285	466
2. Red	56,006	26,292	4,935
3. Sulphur	3,688	----------	----------
4. Cypress	15,884	615	93,892
5. Sabine	35,474	27,007	80,322
6. Neches	394,087	159,572	192,424
7. Trinity	284,567	178,660	240,241
8. San Jacinto	73,466	4,773	8,800
9. Brazos	191,534	151,598	939,121
10. Colorado	71,793	197,096	8,514,771
11. Lavaca	----------	3,073	----------
12. Guadalupe	4,162	24,142	2,374,583
13. San Antonio	30	20,068	300
14. Nueces	23,107	7,553	24,309
15. Rio Grande	89,107	933,211	946,343
16. Coastal	952,985	87,373	764,321
17. Rio Grande drainage	124	22,526	122,772
Total	2,196,012	1,843,844	14,307,880

The column marked "Nonconsumptive" in table II includes all other uses, excepting municipal, mining (including water flooding in oilfields), industrial and irrigation. Nonconsumptive uses are generally regarded as hydroelectric, including power heads, recreation waters, etc. (Many of the power developments are tandem or series operations and therefore accumulative, tending to show more water than could be expected to be available from the stream or from storage figures as provided in table I.)

TABLE III.—*Estimated withdrawals of ground water in Texas by basins for 1957* [1]

[In acre-feet]

Basin	Municipal	Irrigation	Industrial	Total [2]
Canadian	30,000	450,000	50,000	530,000
Red	29,000	2,314,000	11,000	2,354,000
Sabine	8,000	2,000	2,000	12,000
Neches	12,000	16,000	40,000	68,000
Trinity	50,000	21,000	17,000	88,000
San Jacinto	108,000	90,000	95,000	293,000
Brazos	66,000	4,103,000	27,000	4,196,000
Colorado	35,000	779,000	11,000	825,000
Lavaca	3,000	98,000	1,000	102,000
Guadalupe	11,000	3,000	2,000	16,000
San Antonio	106,000	45,000	25,000	176,000
Nueces	20,000	236,000	1,000	257,000
Rio Grande	69,000	1,271,000	20,000	1,360,000
Coastal areas	39,000	165,000	56,000	260,000
Total	586,000	9,593,000	358,000	10,537,000

[1] There is no legal requirement providing for reporting ground water uses.

[2] Does not include withdrawals for domestic, stock, and miscellaneous uses.

The facilities for withdrawing municipal ground water are utilized to approximately 50 percent capacity, but it should be recognized that when peak demands are imposed, that the annual withdrawal capacity of facilities must be regarded as being fully utilized during these peaking periods, even though there may be unused capacity during months when water demands are low. Peak days in municipal use usually are twice the average day's use, with peak hourly demands as much as twice the total use for the peak day. These factors must be taken into account when adequacy of facilities for withdrawal and use are considered.

C. Fundamental problems

The rainfall, varying widely from season to season and from year to year, often produces runoff which has no direct relationship to the total amount of water falling within the year. For instance, a slowly falling rain may produce little or no runoff from a dry and readily absorbent type of terrain; whereas, the same amount of rainfall received within a short period of time and falling on a less absorbent surface may produce runoff that can and often does cause flash flooding. In referring to plate 2 of the appendix, it is noteworthy that in terms of annual runoff, 1 acre in the eastern part of the State produces 1¼ acre-feet of water; while in parts of far west Texas it requires 175 acres to produce that much runoff. Also, the semiarid western half of the State has high evaporation rates (as much as 10 feet per year) and a minimum number of desirable reservoir sites.

The topography of Texas is, in general, rolling to flat type of country in the upper sections, and along the Gulf Coastal Plain there are even fewer reservoir sites than in the upper parts of the State. The Hill Country belt of central Texas offers several desirable sites, but some of them have been developed or are under study and investigation.

Texas has been keenly aware of its overall water problems and is attempting to do something about them. In 1957, Texas voters adopted a constitutional amendment providing a $200-million loan fund to assist political subdivisions in financing the construction of surface water supply projects. Loans are available up to one-third of project cost or $5 million, whichever is the lesser, with the State accepting junior-lien bonds as security. The Texas Water Development Board was created as the operating agency.

In the same year the Governor appointed a statewide water planning committee of more than 150 members.

The Governor's first called session of the 55th legislature enacted the Texas Water Planning Act of 1957 which, among other things, provides for the preparation of "a report to be submitted to the legislature on the water resources of the State with a correlation and relationship of these resources with recommendations to be made to the legislature for the maximum development of the water resources of the State." To carry this out, a planning division was established within the board of water engineers, and funds were provided for the beginning of a topographic mapping program, the first in over 30 years. Satisfactory maps are available for only about 25 percent of the State, most of which covers territory in the gulf coast area and in the eastern portion of the State, or local areas selected for military purposes. If the program as initiated is continued for approximately 15 years, the State will have adequate coverage for appropriate areas under study for surface water resources projects.

By enactment of S. 4266, 85th Congress, 2d session, the Congress created the U.S. Study Commission—Texas, and stated that "it shall be the policy of Congress to recognize and protect the rights and interests of the State of Texas in determining the development of the watersheds of the regions herein mentioned and its interests and rights in water utilization and control, as well as the preservation and protection of established uses." The foregoing quotation is from section 2(1) of that Senate bill. However, in some instances where Federal water projects have been authorized and developed in Texas, there is confusion presently existing as to the authority of the State to administer the acquisition and protection of rights to the use of water within its boundaries, and this confusion develops from and is being added to by decisions of the Supreme Court, and the interpretations placed on some of those decisions tend to indicate that they do not track the policy set out in S. 4266. It may be that the Select Committee on National Water Resources, U.S. Senate, will not concern itself with Federal-State relationships involving water developments, but it is a condition that merits the most careful legislative attention of the Congress in order that further conflicts and confusion will be avoided and harmony between all levels of government can be maintained in the interest of water development. Much of this confusion has evolved from the proprietary activities of the Federal Government in constructing and operating water projects, and as these proprietary activities expand to involve control of additional water supplies, it is inevitable that problems will arise that can be handled only in legislation by the Congress to insure the continuing rights of the States to administer the acquisition of water rights and to fully protect rights acquired under State law.

D. Ground water problems

There are no serious ground water problems that exist in Texas that do not exist elsewhere. Ground water in Texas is legally recognized as being subject to capture by the holder of the surface rights or his assignee, and in the interest of conservation, the legislature has provided for the creation of undergound water conservation districts, the rules and regulations of which are locally administered after the districts are created in accordance with State law. As stated above, the ground waters, of the State are not uniformly distributed and the mineral quality of the water is also highly variable with the great portions of the poor quality of water being in the drier portions of the State (pl. 7 of appendix). There are, however, some excellent ground water deposits west of the 100th meridian, the major one of which is the Ogallala formation in the Texas High Plains area. It is generally conceded that the discharge or withdrawal rate in this formation exceeds the recharge rate, with the degree of difference varying with the rainfall, evaporation rates, types of crops grown, etc., because irrigation accounts for practically all of the water withdrawn from that aquifer. There are no known available surface waters in this section that can be developed to supplement this use of ground waters for irrigation in the Texas High Plains area, and it is for this reason that the mining of the ground water is of concern to many people in that part of the State.

Recharge practices employing artificial means have not been extensive in Texas and there are some aspects of the problem yet to be worked out. It is generally conceded that successful ground water recharge will require some pretreatment of water before it is put into the formation, except in areas where aquifers with high porosity and permeability—such as limestone formations of cavernous and honeycomb types—are found.

The lack of data on the quantities of ground water in storage, together with information on quality and a limit on safe withdrawal rates from each aquifer, is probably the greatest problem involving ground-water use. Withdrawals exceed recharge rates in some sections and to bring use into balance with safe withdrawals of ground water, surface supplies are being developed where surface waters are available. Heavy withdrawals in the Houston-Galveston area have been credited with an appreciable amount of subsidence in that vicinity and to mitigate this condition the city of Houston is turning more and more to surface water for its growing needs. Dallas and Fort Worth have long since developed surface supplies, even though they are located in the area that is underlain by the Trinity Sands, but these sands are not prolific enough to satisfy the municipal and industrial demands of those cities. San Antonio is also facing the problem of supplementing its ground water supply with surface water from some basin to the east, and El Paso added a supplementary surface supply in the early forties.

The trend for most areas of Texas is toward adding surface water as a supplementary industrial and municipal supply or accepting surface water in toto as the only source that has long-time dependability.

E. Water use for pollution abatement

Although there are some streams in Texas with excess water available for dilution to abate pollution, article 4444 of Revised Civil Statutes of Texas and article 698b of the Penal Code strike at the source of the problem by forbidding the discharge of pollutants into any watercourse or public body of water. Thus, manmade pollution is prohibited by law. Enforcement agencies active in this field comprise the Water Pollution Advisory Council (art. 7621a of Texas Civil Statutes) whose members represent State health department, board of water engineers, game and fish commission, railroad commission, and attorney general.

To the extent that natural pollution can be treated successfully by artificial means, such should be done. Studies are now underway in Texas to locate sources of natural pollution and to devise means of abatement.

The policy of Texas is that use of water for pollution abatement by dilution should be avoided wherever possible and used only as a stopgap measure until the cause of the pollution can be eliminated.

II. PROJECTIONS OF FUTURE DEMANDS FOR WATER AND WATER RELATED ACTIVITIES CONSIDERING RELATIONSHIPS OF AVAILABILITY AND COSTS (SUPPLY-DEMAND RELATIONSHIPS)

A. Population projections

Trends in population exert a marked influence on water requirements. Large numbers of people are migrating to Texas from other States, and there is also a well-established trend indicating a shift of population from the farm to the city. Best estimates are that by 1975 the total population of the State will be 13.8 million; by 1980—15 million; and by the year 2000 the population will increase to 18.9 million.

B. Municipal water use

The Board of Water Engineers of the State of Texas contracted with the bureau of business research of the University of Texas for a water requirement survey for the years 1965, 1975, and 2000, and the summary of those water requirements are shown below:

TABLE IV.—*Summary of water requirements (cities over 5,000 population)*

[Acre-feet per year]

Study area	1965	1975	2000
Canadian River Basin:			
Industrial	106,079	148,475	166,309
Nonindustrial	48,359	66,985	96,872
Total	154,438	215,460	263,181
I-D:[1]			
Industrial	3,247	6,377	9,308
Nonindustrial	4,333	6,049	7,777
Total	7,580	12,426	17,085
Red River Basin:			
Industrial	14,728	17,971	23,661
Nonindustrial	52,429	69,630	104,879
Total	67,157	87,601	128,540
Sulphur River Basin:			
Industrial	954	1,089	1,271
Nonindustrial	3,744	4,803	7,424
Total	4,698	5,892	8,695
Cypress Creek Basin:			
Industrial	25,033	27,644	29,980
Nonindustrial	6,644	8,792	12,472
Total	31,677	36,436	42,452

[1] I-D is an area which involves a narrow strip across the northern uppermost portion of the Texas Panhandle.

TABLE IV.—*Summary of water requirements (cities over 5,000 population)*—Continued

[Acre-feet per year]

Study area	1965	1975	2000
Sabine River Basin:			
Industrial	94,064	124,449	214,107
Nonindustrial	45,113	61,347	106,745
Total	139,177	185,796	320,852
Neches River Basin:			
Industrial	146,475	203,601	385,620
Nonindustrial	63,704	87,037	150,940
Total	210,179	290,638	536,560
Trinity River Basin:			
Industrial	53,509	67,859	128,721
Nonindustrial	301,192	394,784	832,486
Total	354,701	462,643	961,207
San Jacinto River Basin:			
Industrial	297,105	432,399	1,063,257
Nonindustrial	163,556	207,072	440,170
Total	460,661	639,471	1,503,427
Brazos River Basin:			
Industrial	169,484	210,705	281,954
Nonindustrial	221,409	303,195	490,422
Total	390,893	513,900	772,376
Colorado River Basin:			
Industrial	67,447	95,573	137,851
Nonindustrial	163,712	214,936	328,695
Total	231,159	310,509	466,546
Lavaca River Basin:			
Industrial	2,007	2,422	2,458
Nonindustrial	6,414	7,828	11,254
Total	8,421	10,250	13,712
Guadalupe River Basin:			
Industrial	25,149	40,419	97,707
Nonindustrial	31,324	41,438	71,379
Total	56,473	81,857	169,086
San Antonio River Basin:			
Industrial	28,948	36,768	63,590
Nonindustrial	146,072	193,512	394,295
Total	175,020	230,280	457,885
Nueces River Basin:			
Industrial	13,123	18,130	31,831
Nonindustrial	23,630	30,056	46,821
Total	36,753	48,186	78,652
Rio Grande River Basin:			
Industrial	29,561	37,072	41,648
Nonindustrial	99,642	143,213	199,914
Total	129,203	180,285	241,562
Coastal area:			
Industrial	408,276	581,099	1,243,600
Nonindustrial	164,424	236,671	457,632
Total	572,700	817,770	1,701,232
Rio Grande drainage:			
Industrial	38,054	69,811	179,514
Nonindustrial	60,887	85,717	151,415
Total	98,941	155,528	330,929
State industrial total	1,523,243	2,121,863	4,102,387
State nonindustrial total	1,606,588	2,163,065	3,911,592
State grand total	3,129,831	4,284,928	8,013,979

If water requirements for 1980 are required, the Bureau of Business Research states that a straight-line interpolation of the water needs for the period 1975–2000 is recommended.

The above table covers water requirements for municipal use for towns over 5,000 population (nonindustrial) and industrial uses, both projected to 1965, 1975, and 2000. It does not purport to include water requirements for irrigation or for general rural uses.

In making the study, the Bureau of Business Research states that it is a basic assumption in all of their studies of water requirements that water used by basic industry must be forecast by first determining the expected growth of each industry, and that nonbasic industry consumption of water be forecast on the basis of population growth and trends in per capita consumption of water.

C. Agricultural use of water

Rapid expansion in irrigation during the past two decades has advanced irrigation farming to a significant position in Texas agriculture. Irrigated acreage within the State increased from 1,045,000 acres in 1940 to an estimated 7 million acres in 1957, accounting for 30 percent of all land growing crops in the State. During 1957, the estimated water used for irrigation of crops approached 12,490,000 feet. Of this quantity, approximately 9.6 million acre-feet were obtained from ground-water supplies and 2.9 million acre-feet from surface water.

At the present time, there is insufficient information to make reliable estimates relating to future water needs for agriculture. Many irrigated areas now depend on water from surface supplies which are inadequate to serve present needs. Ground-water supplies in other irrigated areas are inadequate to sustain present rates of withdrawals for the existing irrigated acreage over long periods of time. There are other potentially irrigable land areas within the State suitable either for temporary or sustained irrigation from undeveloped surface and ground-water resources. In future planning for development of water resources in Texas, reliable estimates of future water needs for irrigation should be made and kept current with periodic revisions to reflect changing conditions.

As part of the preparation of a statewide water plan, the Board of Water Engineers of Texas will study, on a basin and selected area basis, future water needs for irrigation. These studies will take into consideration available land resources physically suitable for sustained production of agricultural crops under irrigation, types of adapted crops and their water requirements, and available water supplies which could be economically developed to meet such needs.

D. Water needs of industries (including atomic)

The Board of Water Engineers of the State of Texas, operating in cooperation with the water committee of the Houston Chamber of Commerce, will conduct an industry by industry type of water needs survey with respect to the probable expansion of each type of industry in the entire Gulf coast area (from the Sabine to the Rio Grande), together with an exploration of the amounts and quality of water which will be required in process work, as well as for cooling purposes. It is contemplated that this exploratory investigation will be joined by the technicians of industry, together with the trade associations concerned, and that a closer analysis of water needs, both quantity and quality, can be made than is now available. This project is getting under way and should be showing real accomplishments before many months. It will also include studies leading to greater economies in the use of water for industrial purposes. This will be a recheck and evaluation of the survey made by the Bureau of Business Research of the University of Texas.

The State has had no experience with atomic energy and is not in position to make a comment upon the problem of water needs that may be involved in atomic plants.

E. Electric energy

The undeveloped potential for electrical energy by means of hydroelectric power is limited in this State. There is potential development at Diablo Dam on the Rio Grande, at Toledo Bend on the Sabine, and possibly somewhat smaller potentials at several sites on the Brazos and Colorado. Other than these, the hydro potential seems to lack economic feasibility. Where electrical energy is developed by the steam plant method, water requirements are not great, except for dissipation of heat which is on the order of evaporating 1 pound of water for each 1,000 B.t.u. of heat released to recirculation water taken from the stream or lake. Where cooling towers are used in connection with these, additional factors are to be taken into account, but the overall water requirements for generation of electrical energy by steam plant methods are not great.

F. Navigation

Navigation has not imposed an appreciable burden upon the water supply of the State. Some navigation water is set aside in the upper Trinity, but the quantity is small and the State has no definite information as to fresh water needs for future navigation projects in the State. The Corps of Engineers is the logical source of information on water needs for navigation in Texas.

G. Flood control

Flood control studies are being made by the Corps of Engineers and the Soil Conservation Service and by certain flood-control districts. Flood control, as such, holds no great overall impact for water supplies, except as it may be developed jointly in multipurpose structures involving municipal, industrial, and irrigation water. It is suggested that multipurpose developments be restudied with respect to the allocation of costs. Historically speaking, local districts, counties, cities, towns, and private capital in Texas have accomplished almost all of the flood control in the State prior to the acceptance of this as a responsibility by the Federal Government. Large sums of money have been expended by levee and flood-control districts, counties, cities, and other interested parties for reclamation purposes, but since the Federal Government has entered this field, it is anticipated that most of the funds to be expended for flood control in the future will be through Federal appropriations. If flood plain zoning is indicated, cooperative efforts should be developed in this field with the State taking the lead.

H. Water recreation

Recreation activities around many of the larger bodies of water that have been developed in Texas are on the increase and this increase can be expected to grow. People have more time to use these facilities than they did prior to the 40-hour workweek, and the distance has been shortened by virtue of better highways, more and better cars, and other traveling and camping facilities required to reach and enjoy these recreation spots. It is suggested that the committee may want to review this phase of water use very carefully where Federal projects are to be developed and consider recommendations for determining the nonreimbursable allocations for recreation.

I. Fish and wildlife

Fish and wildlife culture and propagation does not impose a great burden upon the water supplies of the State in terms of quantities and therefore offers no particular problem, although these are most important related interests.

J. Trends in use of water for waste disposal

The trend in Texas is toward a higher degree of treatment for both municipal and industrial wastes and a reuse of this water, rather than the use of impounded fresh waters for dilution or as a means of waste disposal (see I–E, p. 10). Many municipalities, to avoid dumping of waste in streams, are selling sewage for use in industry and to irrigate crops not destined for human consumption. Industry has studied and is using on a limited basis a system of injecting wastes to highly mineralized subsurface strata. The latter practice is prevalent in the oil industry, and the Railroad Commission now requires producers in many Texas oil fields to reinject salt water produced with oil.

III. MEANS OF MEETING FUTURE DEMANDS (NEW TECHNIQUES)

A. Conventional methods of adding new supplies and costs thereof

There is at the present time no substitute which can be used for developing new supplies and costs thereof that will supplant the conventional methods of impounding water or drilling water wells, and from a review of the technical literature there seems to be none on the horizon.

B. Vegetational management (reduction of evapo-transpiration)

Vegetational management obviously offers some means of reduction of evapo-transpiration, but no research has been done in the Southwest to substantiate a statement that it would be a feasible approach.

C. Weather modification (induced precipitation)

Weather modification to induce increased precipitation has also been considered by the technicians as well as by legislative committees. This offered great interest during the last drought, but when the rains came the popular interest was lost. The committee could well carry forward a broader study of weather modification based on a research of cloud dynamics, flow of air currents, distribution of heat balance by air movements, and other kindred topics involved in precipitation.

Weather modification in the Great Plains region would no doubt involve a different approach than would be used for weather modification in coastal areas, but there are too many arid regions in the United States that need additional water to overlook this possibility of adding to their water supply, even though present studies have not shown that the supply can be greatly increased by presently used methods.

D. Evaporation reduction and seepage control

In areas where evaporation dissipates great quantities of water, there is the possibility of reducing some of these losses by applying monomolecular chemical films to the water surfaces, but many problems have yet to be worked out before the theoretical savings indicated by laboratory methods can be approximated. Texas is carrying on a research program in this field at the present time and is very encouraged with the possibility of using this method of reducing water losses from small impoundments, such as farm and ranch stock tanks and other small bodies of water. The work is now in the field phase of investigation and is being conducted jointly with the Department of Interior, the Board of Water Engineers, the Texas A. & M. Research Foundation, the Southwest Evaporation Research Council, and other interested parties in the State.

E. Desalinization

There are a few areas in the State where desalinization would be economically feasible, but the areas are limited. As a research investigation it should be carried forward in order that the lowest possible cost and the most practical methods may be developed for use in areas where the conventional methods of developing new supplies are not applicable because of great distances to be traversed or because of lack of acceptable supply at any cost. It is entirely possible that the present methods and procedures used in desalinization may produce water at costs acceptable to certain industries and towns that have no other supplies, but if costs are to remain near $1 per 1,000 gallons without considering debt service and other costs which are normally included where private capital is used, much research is yet to be accomplished. This research should be supported by very accurate cost figures, because it is in this field that the main concern is now centered.

Because of high cost, desalinization to develop irrigation water seems to be out of the question. It is believed the research to be conducted at the Federal pilot plant at Freeport, Tex., will provide many answers to the perplexing questions of cost, feasibility, etc.

F. New techniques in multiple purpose river management

The experience of the Lower Colorado River Authority, a State agency, provides a lesson in proper river management. Six dams above Austin, Tex., provide millions of acre-feet of flood control and conservation storage. Water is converted into hydroelectric energy at each dam and is used and reused for this purpose. Releases are timed to occur most frequently in the summer months when the water is in demand for irrigation in the coastal areas downstream. As the water reaches Austin and other cities below, some is diverted and used for municipal and industrial purposes, with treated effluent being returned to the stream to replenish the supply. By the time the water, which may have fallen as rain in far west Texas, finally reaches the gulf, it has been fished in, bathed in, boated upon, turned turbines to generate electricity, provided cooling for industry, served numerous municipal systems, and finally has irrigated rice, cotton, and other crops. This is river management at its best and serves as an example for other areas.

The improper location of an industry that discharges an appreciable amount of waste into a stream can destroy the usefulness of the stream for great distances. Quality in the downstream sections can be impaired to where the water will not be acceptable for municipal, industrial, and possibly other uses. Uncoordinated efforts to obtain industries of this type for upstream locations should be discouraged. Quality in the downstream portions of rivers may be as important as quantity and probably in some instances more so, and for this reason the techniques in multipurpose river management should be developed before great damage is done in impairing the quality of the water beyond recovery by normal treatment methods.

G. Effects of nuclear energy

Texas has had no experience in this field.

H. New technical methods of improving water supply methods (improved ground water use, water recovery, etc.)

The new technical methods available to the average user in improving his water supply may have much to offer, but will have strong appeal only in certain areas. Better use of water, more reuse of water, and the recovery of water for secondary purposes should be encouraged, and quite a bit of educational work is being done because of previous water shortage experiences. Better irrigation practices are needed in many areas in the State and the agricultural experiment stations are mindful of this need. Reuse of water which has passed through sewage systems and sewage treatment plants in industrial processes is meeting with a lot of favor in Texas, and this is being expanded in water-short areas, because in those areas there is no additional water which can be brought in at costs which are considered reasonable. In those areas the economy will have to be adjusted to the available water, and industrial locations will have to be selected on the amount of water and the quality of water that they use and the waste which they produce.

Texas could recover for beneficial use great quantities of water which are now being rendered unusable by natural pollution if funds were made available for the proper types of engineering studies to develop the techniques needed to remove this mineral pollution. In certain areas of the upper Brazos Basin and in the upper Red River Basin there are large deposits of water-soluble minerals which reach the stream in solution form, either by being dissolved in runoff or by being bled in the stream from seeps and springs. The formation that produces these highly mineralized waters swings from southeastern New Mexico through the lower Panhandle portion of Texas, extends through Oklahoma and on into Kansas, and the area is generally referred to in Texas as the Cap Rock region. Collecting enough technical data and information to make it engineeringly feasible to recover this water by diverting the salt pollution or otherwise removing these salts from the streams will involve large expenditures, but any attempt to correct these conditions without adequate information could lead to even greater loss of money. Since this problem involves New Mexico, Texas, Oklahoma, and Kansas, it is suggested that the Federal Government may find that there is a broad national interest involved because of the poor quality of the water in the main stems of the river basins affected. Such a study would be a logical undertaking for the Federal Government because of the nature of the problem, and it is recommended for consideration to the committee. The Congress has appropriated money to make a pollution survey of the Red River-Arkansas Basin, but the problem should be attacked from a geologic and engineering viewpoint in addition to the chemical quality aspects.

SUMMARY

The foregoing outlines in a broad sense some of the water problems of the State of Texas. The State has demonstrated its interest in taking the lead in solving these problems by the creation of the water development fund for providing financial assistance to local political subdivisions and by creating the planning division within the State board of water engineers to carry out the State's responsibilities in connection with developing its own water resources in cooperation with interested Federal agencies. The basinwide river authorities in Texas are charged by law to provide master plans for the development of the water resources of the basins with approval by the board of water engineers to follow, and most all of them have developed such plans. Five basin plans have been approved and two are before the board of water engineers at the present time.

The quantities of water which will be required for municipal and industrial purposes by 1980 does not present an insurmountable financing problem. The summary of the water requirements furnished in table IV shows industrial and municipal requirements for the year 1980 to be between 5 and 5½ million acre-feet per year. At the present time the State is using approximately 3 million acre-feet of water for these purposes, and no great financial difficulties have been encountered. The State could physically develop an additional 20 million acre-feet of conservation storage, but the forecasted needs do not seem to require that this much storage will be needed before 2010 unless irrigation is greatly expanded.

However, it should be emphasized that some water supply projects, meritorious otherwise, are stymied for want of adequate financing, usually at a local level. Consideration should be given to a partnership arrangement between the State and Federal governments that would make funds available in the form of loans to hard-pressed local political subdivisions to finance projects for water conservation and development. Such a venture between the Housing and Home Finance Agency and the Texas Water Development Board is now nearing finalization. In this instance, White River Municipal Water District (composed of the Texas cities of Post, Crosbyton, Spur, and Ralls) seeks a loan of $2,700,000 from the Federal agency and $1,300,000 from the State, the latter's security to be junior lien bonds subordinated to those offered the HHFA. Neither governmental agency encroaches upon the commercial investment field since private finance is not interested in this borderline project. Such an arrangement could well serve as a model means of financing needed water projects in which the Nation, State, and local communities have a decided interest.

The Federal Government can be of great assistance to the State of Texas in carrying forward a program of orderly water development to meet the expanding needs for more water in Texas, but the relationship should be on the basis of the same cooperation and teamwork which now exists with the State taking the lead in planning, coordinating, correlating, and guiding the joint effort and the Federal agencies supplying assistance where and when appropriate. The announced policy of the Congress as set out in the act creating the U.S. Study Commission—Texas and recognized by the Federal agencies in the preparation of Senate Document No. 111, 85th Congress, 2d Session, should be spelled out in legislation so as to maintain in the States their rightful and long-recognized place in the administration of the acquisition and protection of water rights and thereby restore confidence that existed prior to the judicial decisions which have had such a strong impact upon water users throughout the country.

APPENDIX

Plate

1. Average annual rainfall as of January 1, 1956.
2. Zones of runoff in Texas.
3. Surface water reservoirs.
4. Areas supplied by principal water-bearing formations in Texas.
5. Minimum discharge year 1954.
6. Maximum discharge year 1941.
7. Quality of surface water (in three colors, retained in committee files).

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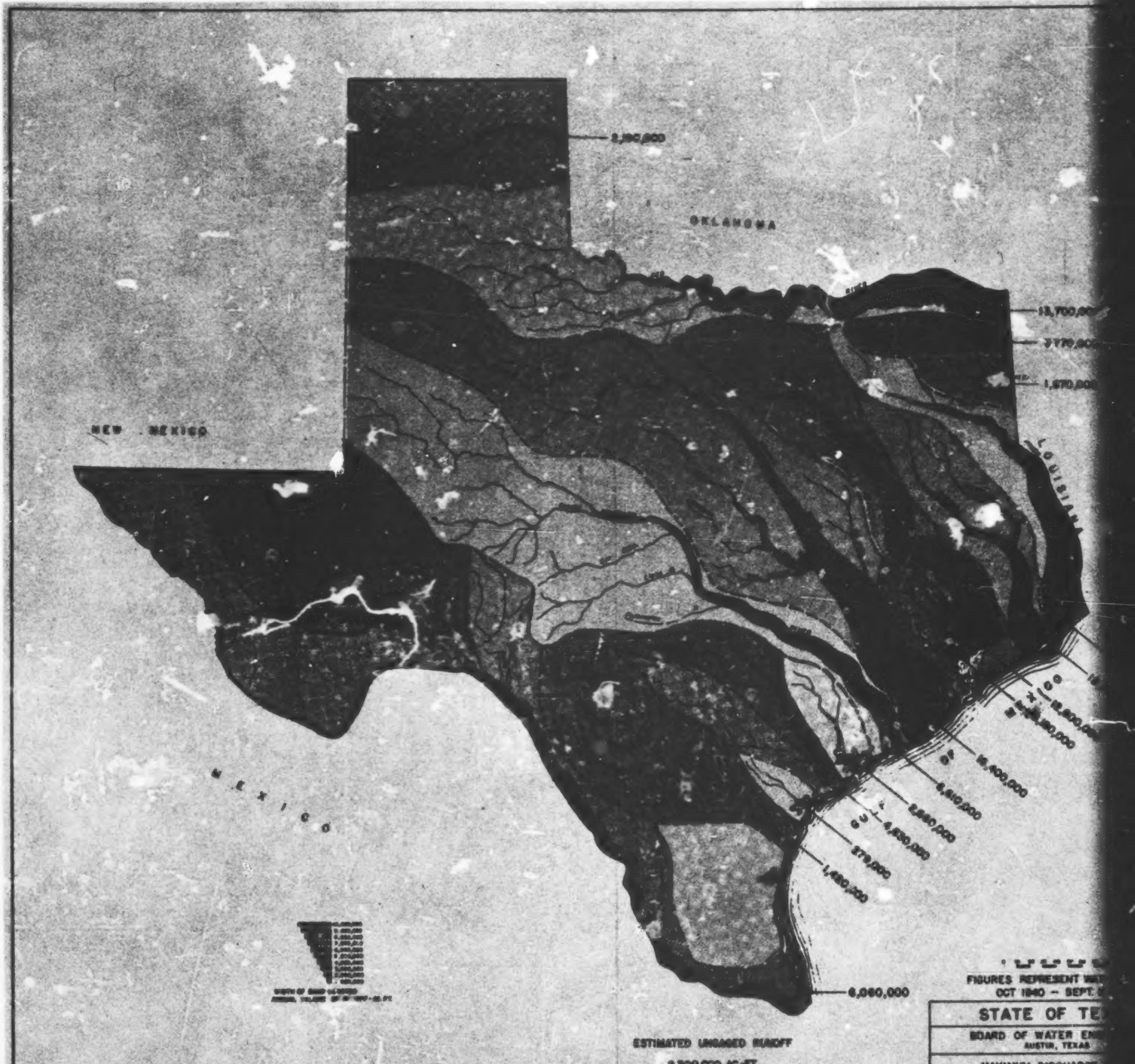
2,190,000
OKLAHOMA
NEW MEXICO
LOUISIANA
MEXICO
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2,770,00
1,870,000
GULF OF MEXICO
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6,610,000
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ESTIMATED UNGAGED RUNOFF
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AUSTIN, TEXAS
MAXIMUM DISCHARGE
1941
TOTAL DISCHARGE 113,000

Plate 6

346a

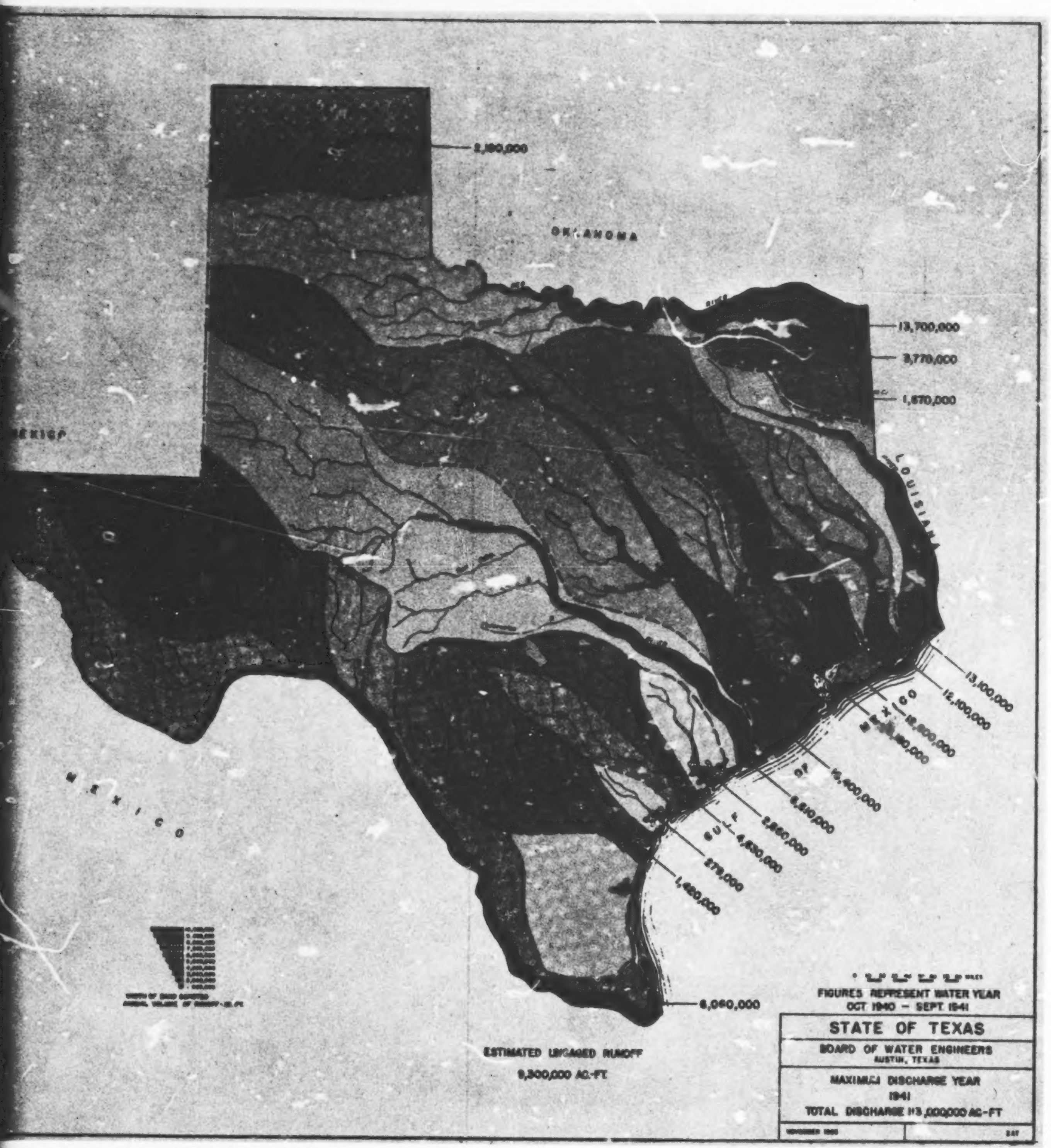

2,180,000
OKLAHOMA
13,700,000
3,770,000
1,870,000
LOUISIANA
MEXICO
MEXICO
GULF OF MEXICO
13,100,000
12,100,000
12,800,000
15,400,000
6,610,000
2,860,000
4,830,000
279,000
1,420,000
6,060,000
ESTIMATED UNGAGED RUNOFF
9,300,000 AC-FT
FIGURES REPRESENT WATER YEAR
OCT 1940 – SEPT 1941
STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
MAXIMUM DISCHARGE YEAR
1941
TOTAL DISCHARGE 113,000,000 AC-FT
347

Plate 6

63198 O - 61 (Face p. 347) No. 5

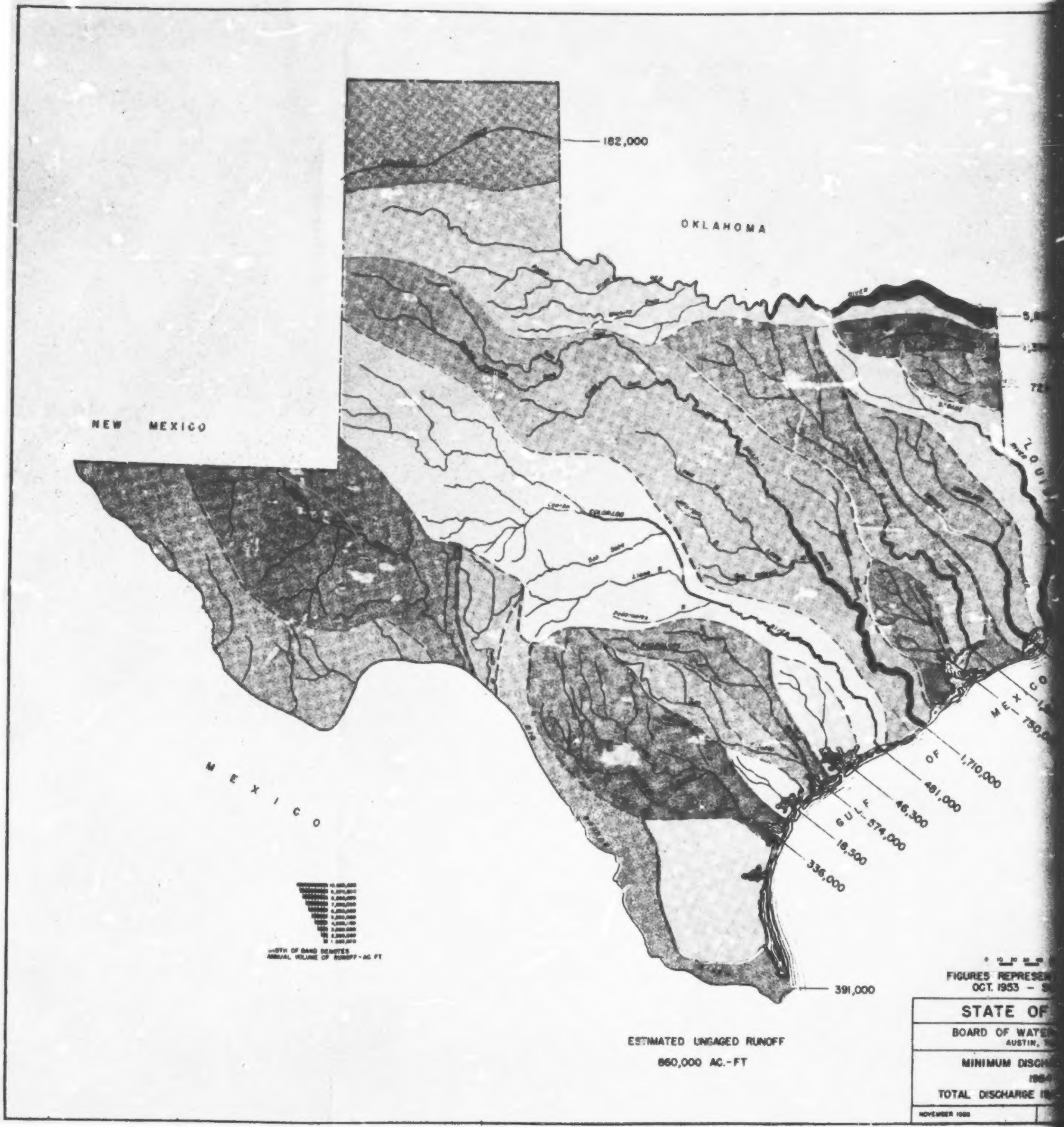

182,000
OKLAHOMA
NEW MEXICO
MEXICO
GULF OF MEXICO
COLORADO
1,710,000
481,000
46,300
574,000
18,500
336,000
391,000
750,0
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
WIDTH OF BAND DENOTES
ANNUAL VOLUME OF RUNOFF - AC FT
ESTIMATED UNGAGED RUNOFF
860,000 AC.-FT
FIGURES REPRESEN
OCT. 1953 - S
STATE OF
BOARD OF WATE
AUSTIN,
MINIMUM DISCH
TOTAL DISCHARGE
NOVEMBER 1955

Plate 5

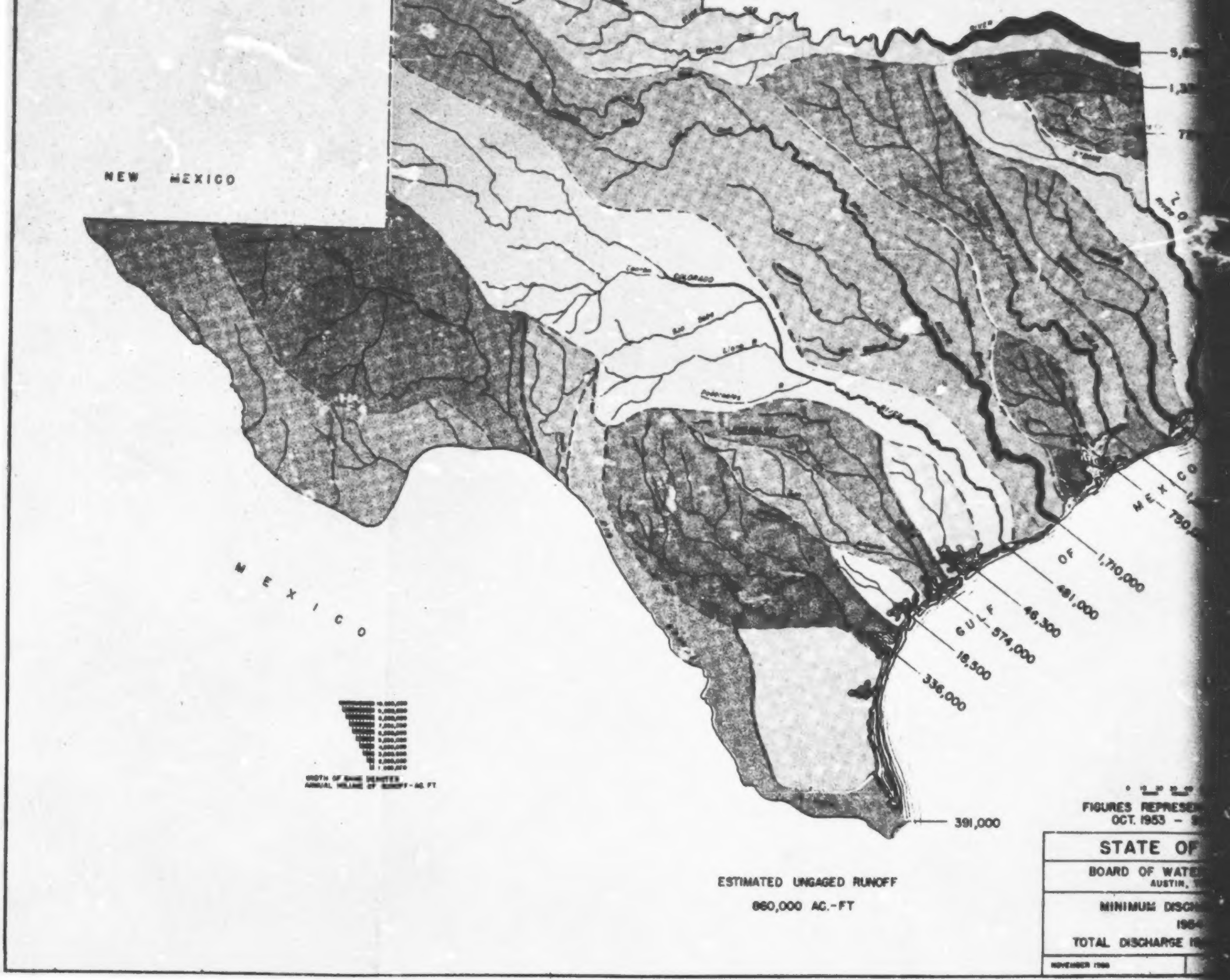

182,000
OKLAHOMA
NEW MEXICO
MEXICO
COLORADO
San Saba
Llano R.
Pedernales R.
5,8
1,3
7
750,0
1,710,000
481,000
46,300
574,000
18,500
336,000
391,000
GULF OF MEXICO
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
WIDTH OF BAND DENOTES ANNUAL VOLUME OF RUNOFF - AC. FT
ESTIMATED UNGAGED RUNOFF
860,000 AC.-FT
FIGURES REPRESE
OCT. 1953 -
STATE OF
BOARD OF WATE
AUSTIN, T
MINIMUM DISCH
1954
TOTAL DISCHARGE I

Plate 5

346 b

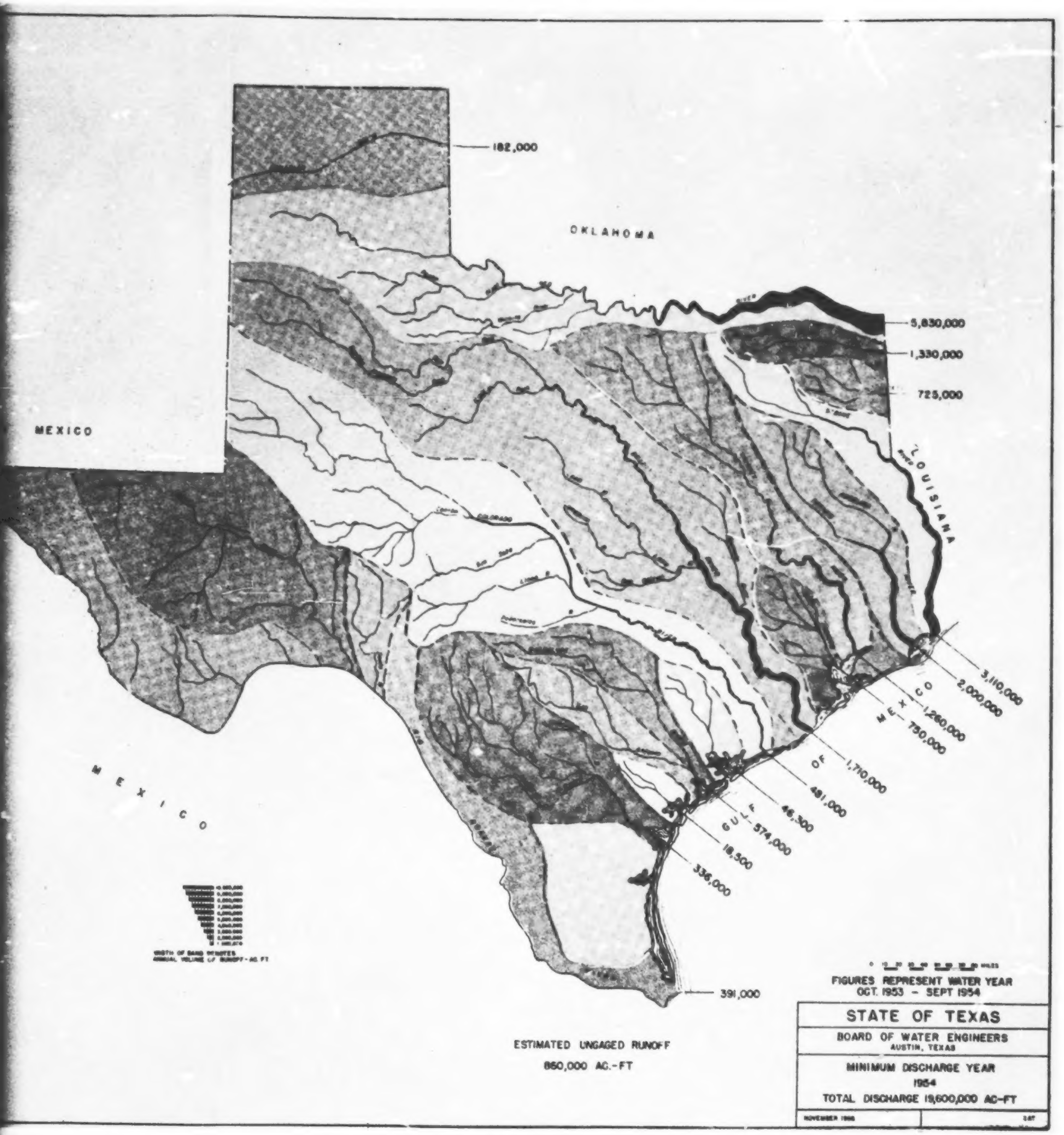

182,000
OKLAHOMA
MEXICO
LOUISIANA
5,830,000
1,330,000
725,000
COLORADO
3,110,000
2,000,000
1,260,000
750,000
1,710,000
491,000
46,300
574,000
18,500
336,000
391,000
MEXICO
GULF OF MEXICO
WIDTH OF BAND DENOTES
ANNUAL VOLUME OF RUNOFF - AC. FT
ESTIMATED UNGAGED RUNOFF
860,000 AC.-FT
0 10 20 30 40 50 60 70 80 MILES
FIGURES REPRESENT WATER YEAR
OCT. 1953 - SEPT 1954
STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
MINIMUM DISCHARGE YEAR
1954
TOTAL DISCHARGE 19,600,000 AC-FT
NOVEMBER 1955

Plate 5

63198 O - 61 (Face p. 347) No. 4

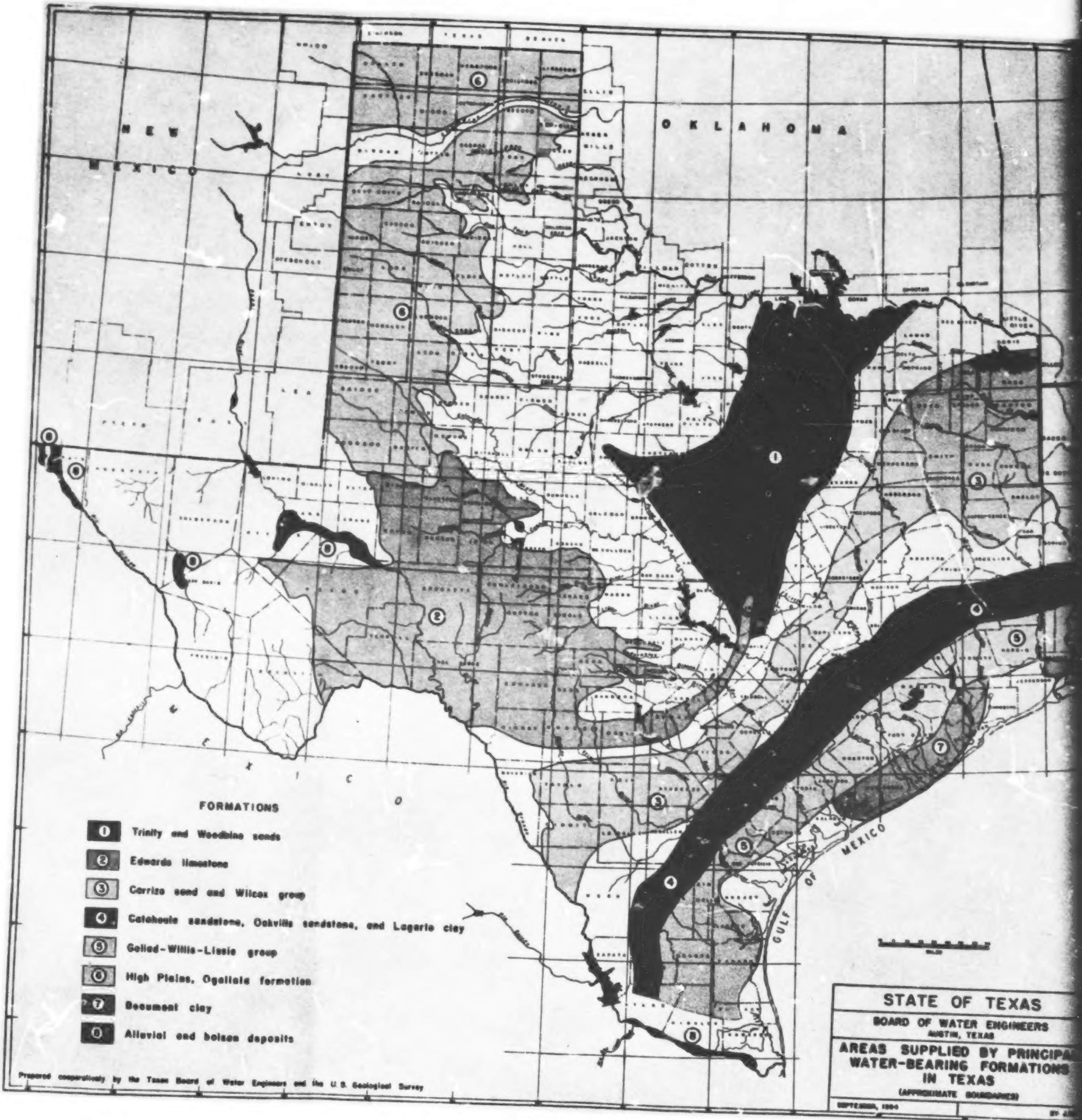

NEW MEXICO
OKLAHOMA
MEXICO
GULF OF MEXICO
FORMATIONS
① Trinity and Woodbine sands
② Edwards limestone
③ Carrizo sand and Wilcox group
④ Catahoula sandstone, Oakville sandstone, and Lagarto clay
⑤ Goliad-Willis-Lissie group
⑥ High Plains, Ogallala formation
⑦ Beaumont clay
⑧ Alluvial and bolson deposits
Prepared cooperatively by the Texas Board of Water Engineers and the U.S. Geological Survey
STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
AREAS SUPPLIED BY PRINCIPA
WATER-BEARING FORMATIONS
IN TEXAS
(APPROXIMATE BOUNDARIES)
SEPTEMBER, 1954

Plate 4

346 C

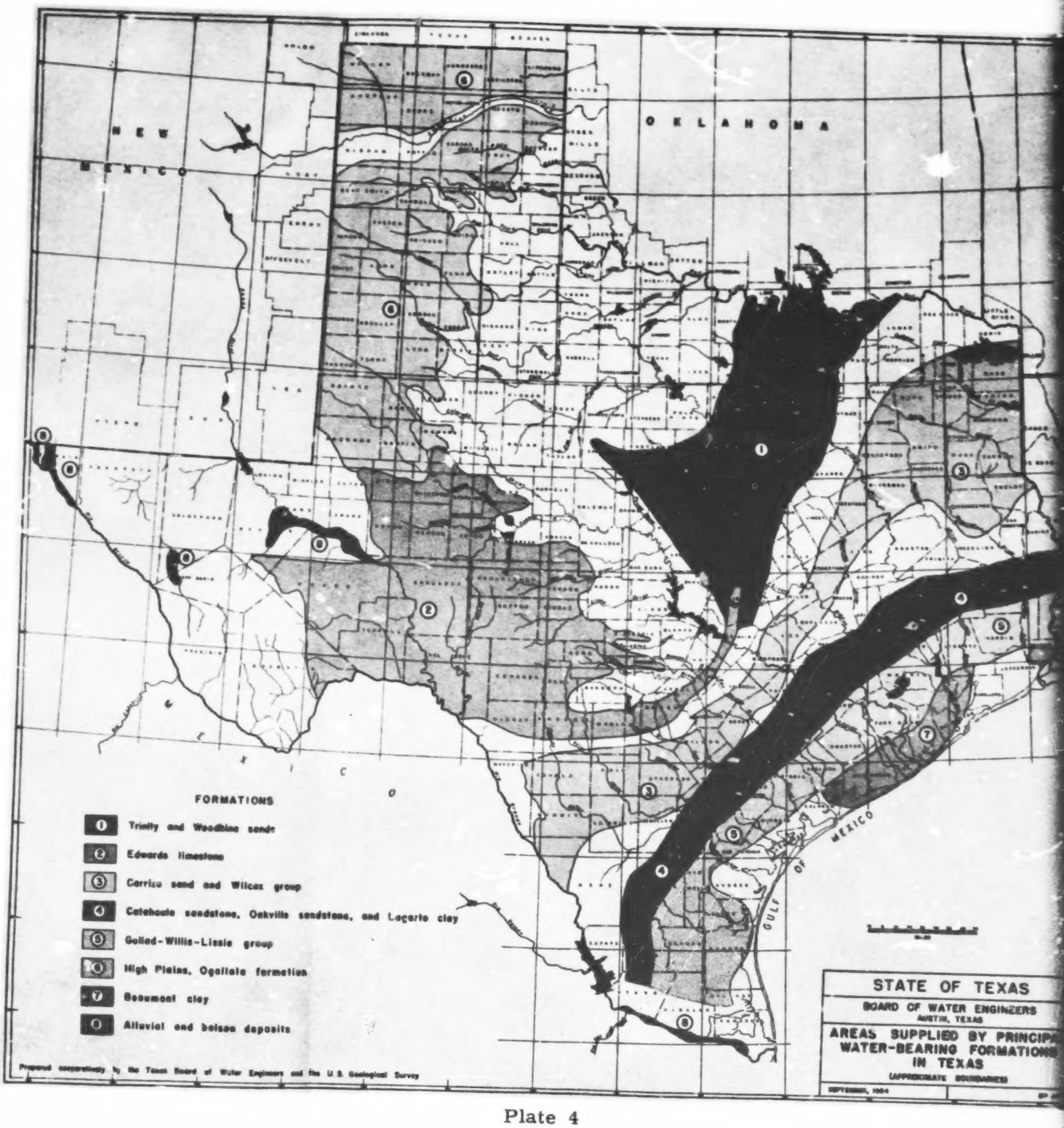

NEW MEXICO
OKLAHOMA
MEXICO
GULF OF MEXICO
FORMATIONS
① Trinity and Woodbine sands
② Edwards limestone
③ Carrizo sand and Wilcox group
④ Catahoula sandstone, Oakville sandstone, and Lagarto clay
⑤ Goliad-Willis-Lissie group
⑥ High Plains, Ogallala formation
⑦ Beaumont clay
⑧ Alluvial and bolson deposits
Prepared cooperatively by the Texas Board of Water Engineers and the U.S. Geological Survey
STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
AREAS SUPPLIED BY PRINCIP
WATER-BEARING FORMATION
IN TEXAS
(APPROXIMATE BOUNDARIES)
SEPTEMBER, 1954

Plate 4

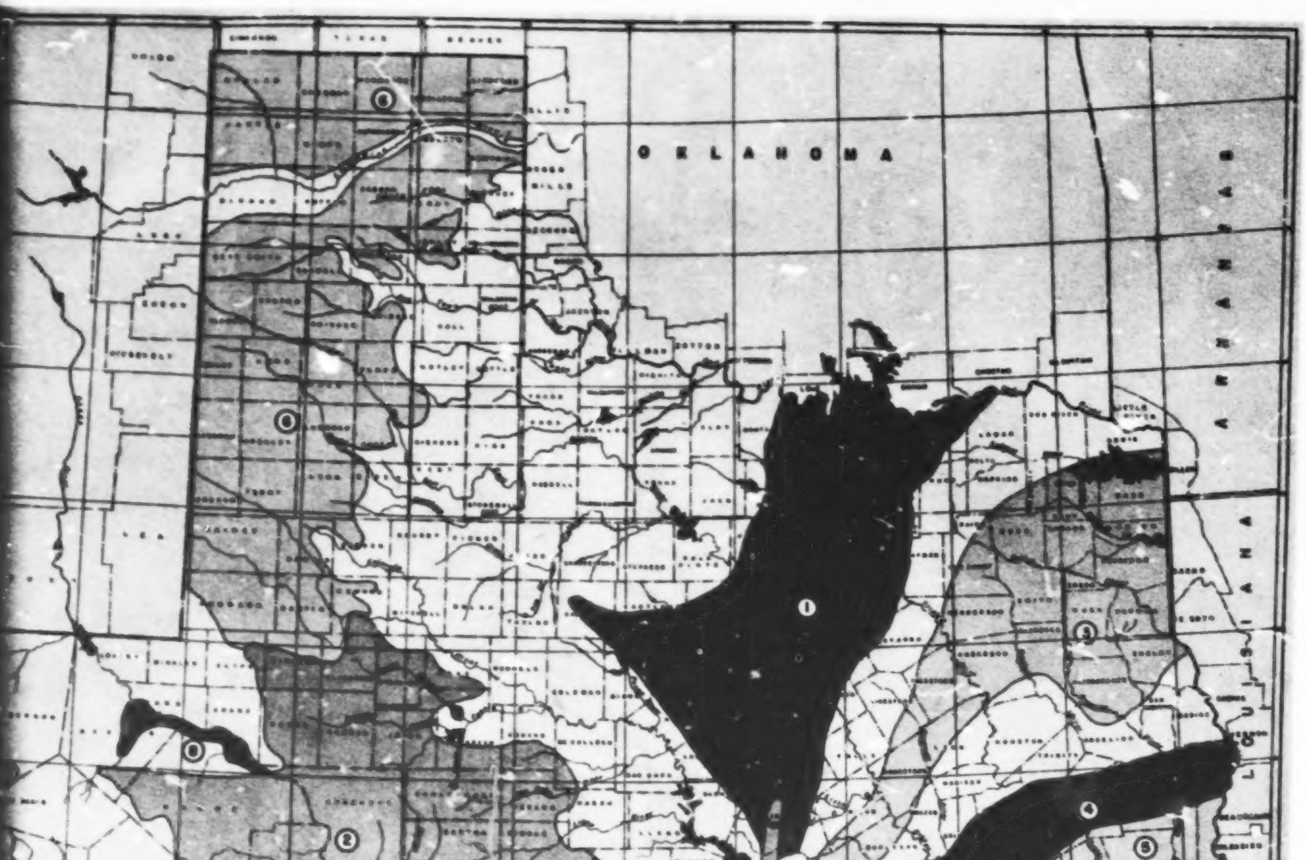
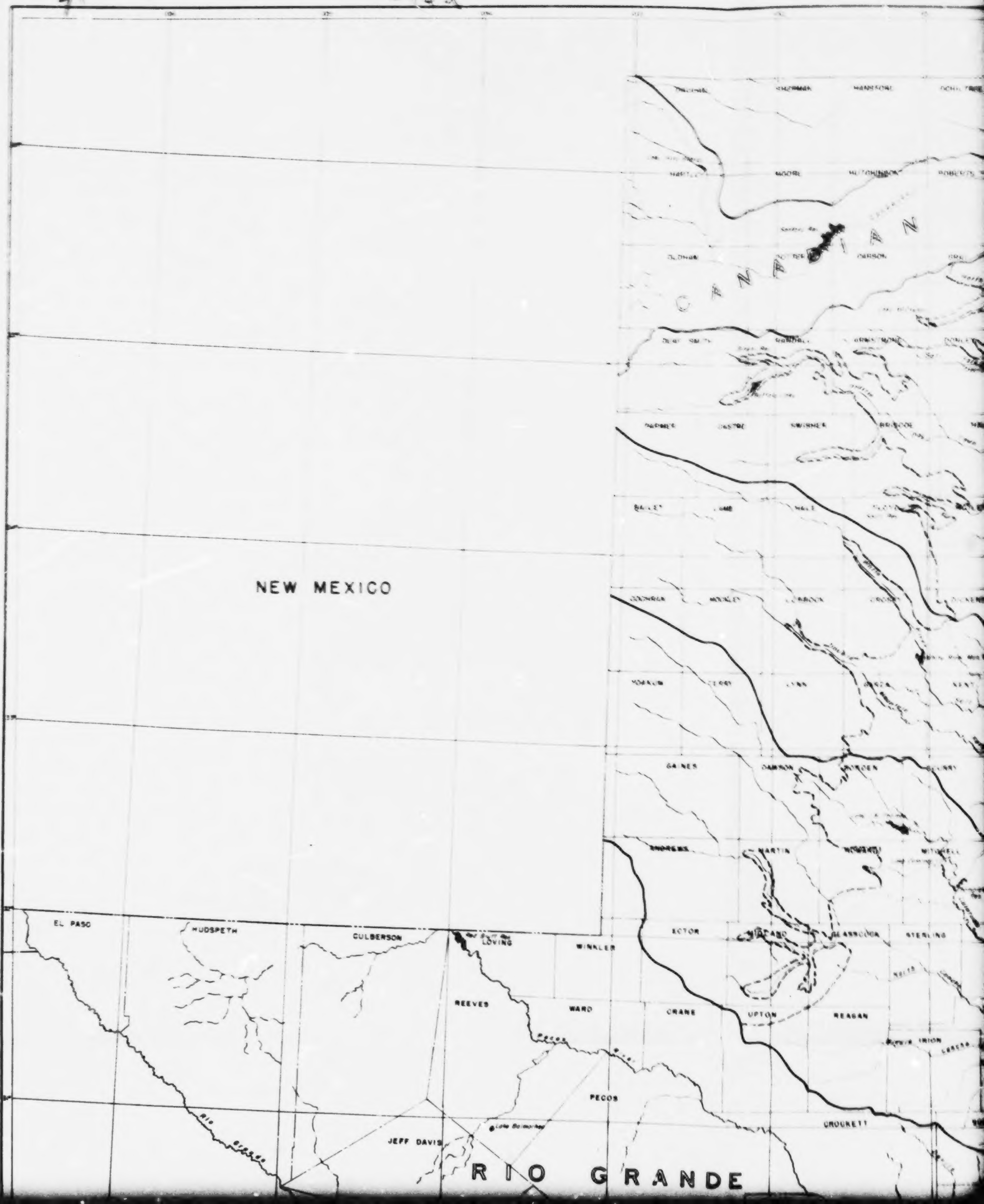

OKLAHOMA
ARKANSAS
LOUISIANA
GULF OF MEXICO
M E X I C O
FORMATIONS
Woodbine sands
…estone
…d and Wilcox group
…sandstone, Oakville sandstone, and Lagarto clay
…e-Lissie group
…, Ogallala formation
…clay
…d bolson deposits
…ard of Water Engineers and the U.S. Geological Survey
STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
AREAS SUPPLIED BY PRINCIPAL WATER-BEARING FORMATIONS IN TEXAS
(APPROXIMATE BOUNDARIES)
SEPTEMBER, 1954
①
②
③
④
⑤
⑥
⑦
⑧

Plate 4

63198 O - 61 (Face p. 347) No. 1

A

344



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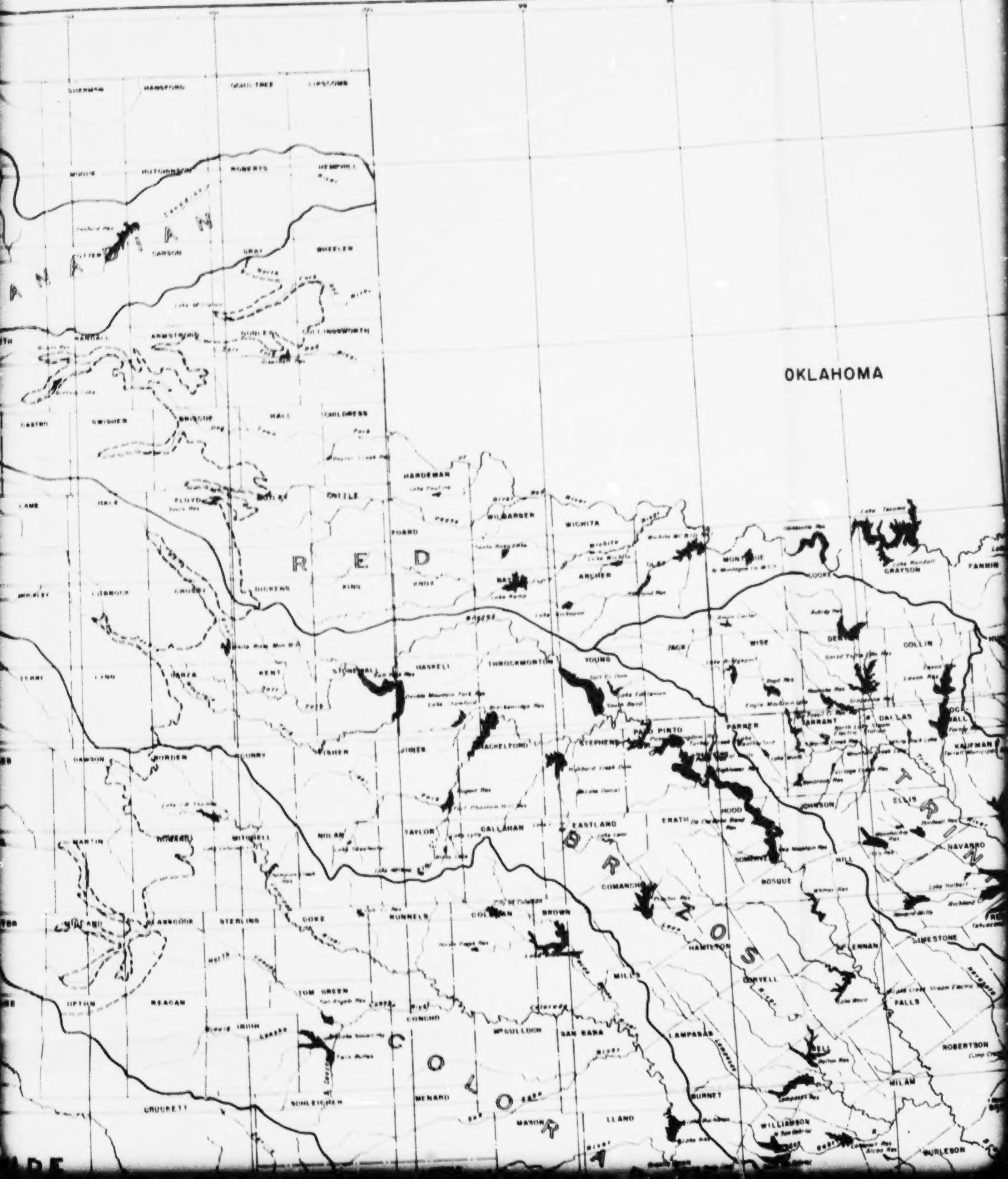
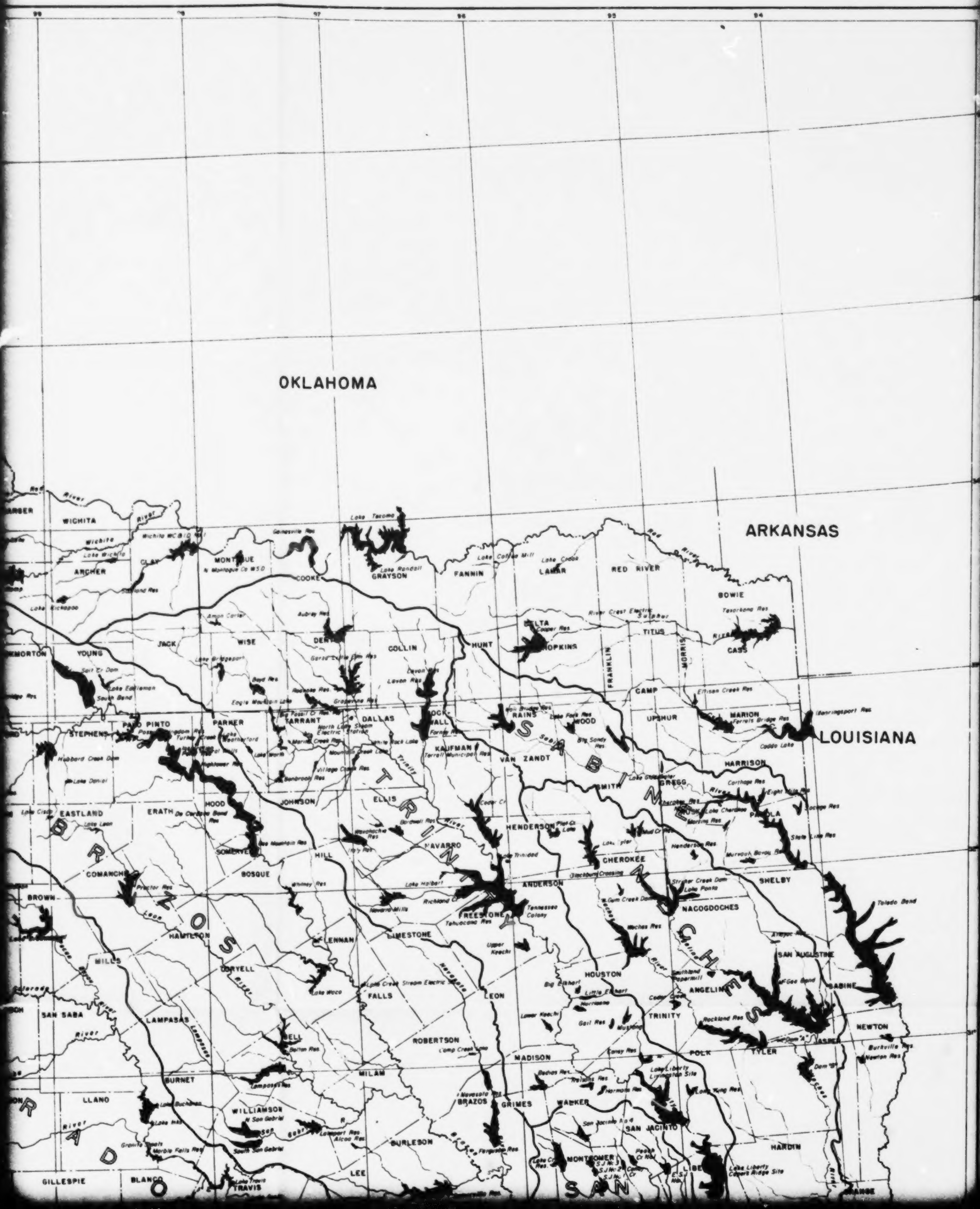
DALLAM
SHERMAN
HANSFORD
OCHILTREE
HARTLEY
MOORE
HUTCHINSON
ROBERTS
OLDHAM
POTTER
CARSON
GRA
C A N A D I A N
DEAF SMITH
RANDALL
ARMSTRONG
DONLE
PARMER
CASTRO
SWISHER
BRISCOE
BAILEY
LAMB
HALE
FLOYD
COCHRAN
HOCKLEY
LUBBOCK
CROSBY
DICKENS
YOAKUM
TERRY
LYNN
GARZA
KENT
GAINES
DAWSON
BORDEN
SCURRY
ANDREWS
MARTIN
HOWARD
MITCHELL
EL PASO
HUDSPETH
CULBERSON
LOVING
WINKLER
ECTOR
MIDLAND
GLASSCOCK
STERLING
REEVES
WARD
CRANE
UPTON
REAGAN
IRION
Pecos River
PECOS
CROCKETT
JEFF DAVIS
Rio Grande
R I O G R A N D E

B

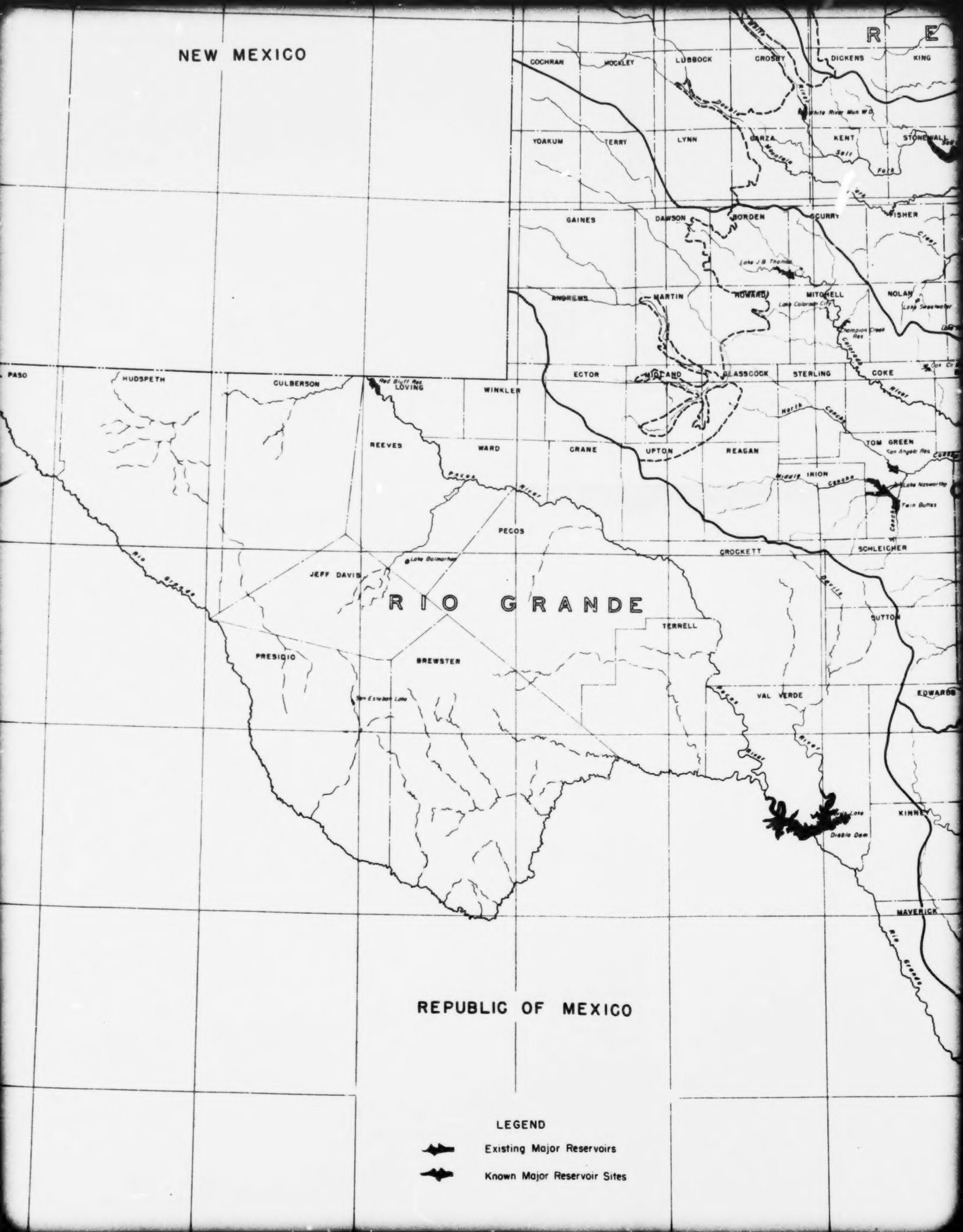

OKLAHOMA
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
CANADIAN
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
CASTRO
SWISHER
BRISCOE
HALL
CHILDRESS
HARDEMAN
LAMB
HALE
FLOYD
MOTLEY
COTTLE
FOARD
WILBARGER
WICHITA
RED
KNOX
KING
DICKENS
CROSBY
LUBBOCK
HOCKLEY
ARCHER
MONTAGUE
COOKE
GRAYSON
FANNIN
Lake Texoma
Lake Kemp
TERRY
LYNN
GARZA
KENT
STONEWALL
HASKELL
THROCKMORTON
YOUNG
JACK
WISE
DENTON
COLLIN
TARRANT
DALLAS
PARKER
PALO PINTO
STEPHENS
SHACKELFORD
JONES
FISHER
SCURRY
BORDEN
DAWSON
KAUFMAN
ELLIS
JOHNSON
HOOD
ERATH
EASTLAND
CALLAHAN
TAYLOR
NOLAN
MITCHELL
HOWARD
MARTIN
MIDLAND
GLASSCOCK
STERLING
COKE
RUNNELS
COLEMAN
BROWN
COMANCHE
BOSQUE
HILL
NAVARRO
BRAZOS
TRIN
McLENNAN
LIMESTONE
HAMILTON
CORYELL
MILLS
FALLS
TOM GREEN
CONCHO
McCULLOCH
SAN SABA
LAMPASAS
BELL
ROBERTSON
MILAM
UPTON
REAGAN
IRION
SCHLEICHER
MENARD
MASON
LLANO
BURNET
WILLIAMSON
BURLESON
CROCKETT
COLO

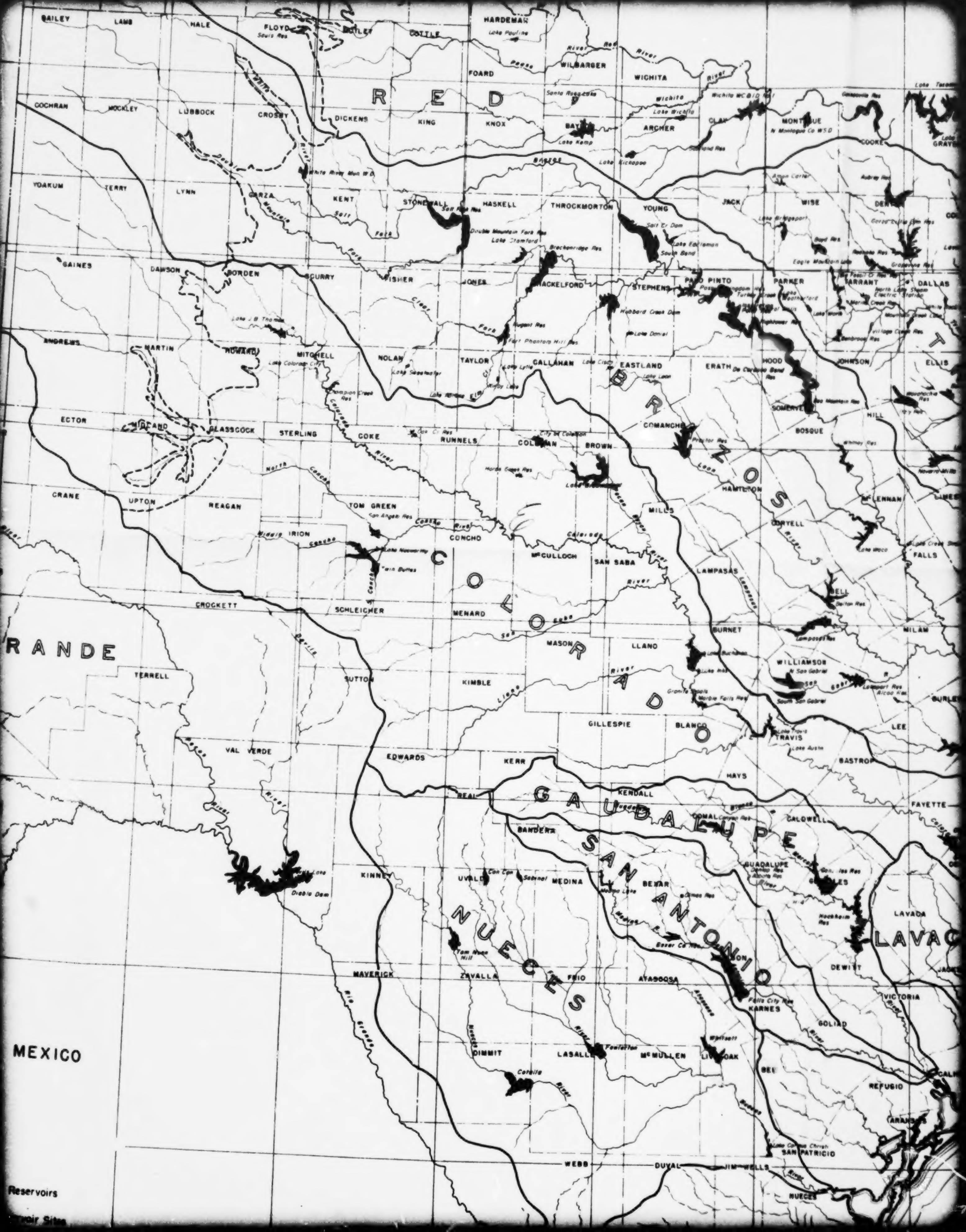
B

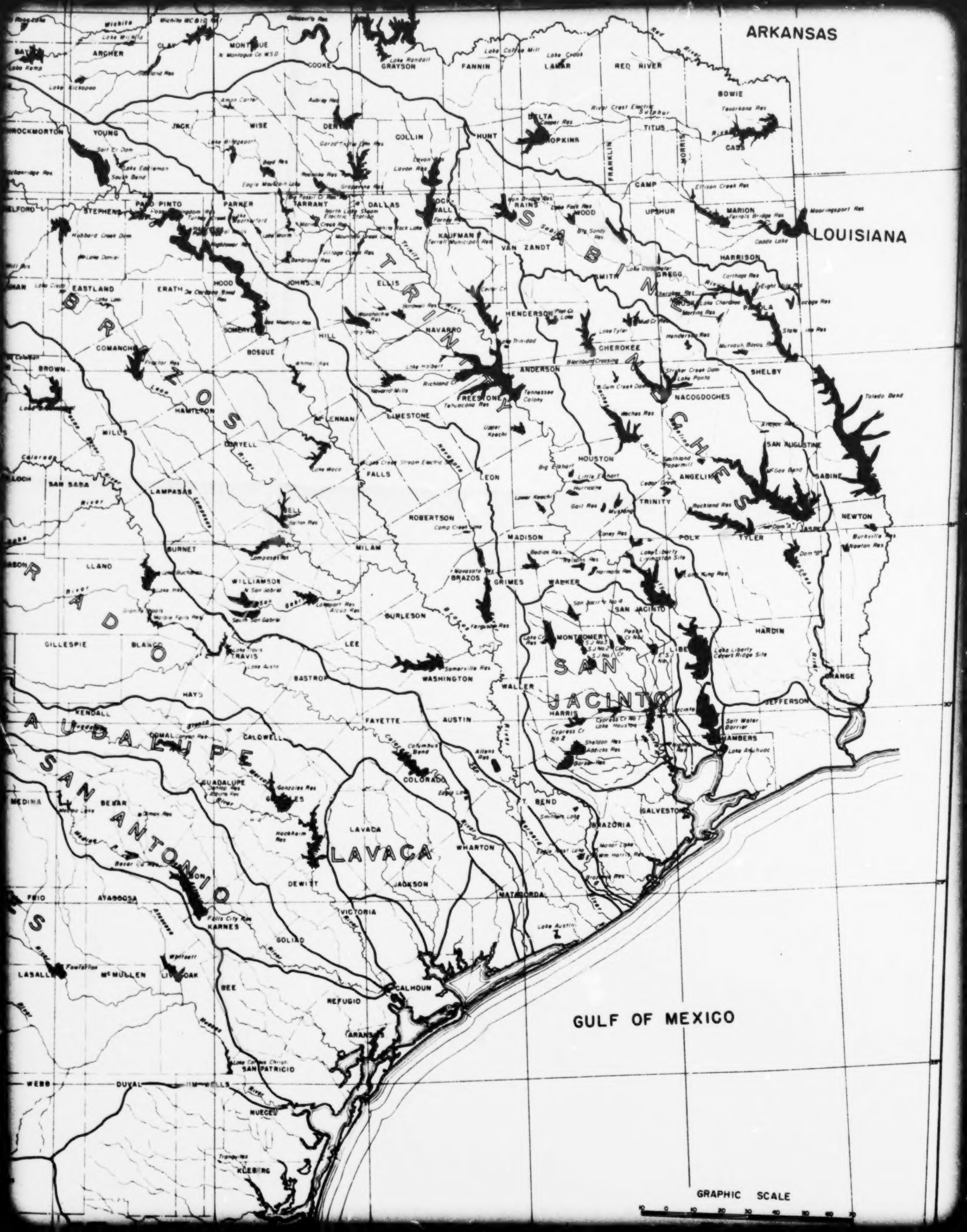
C

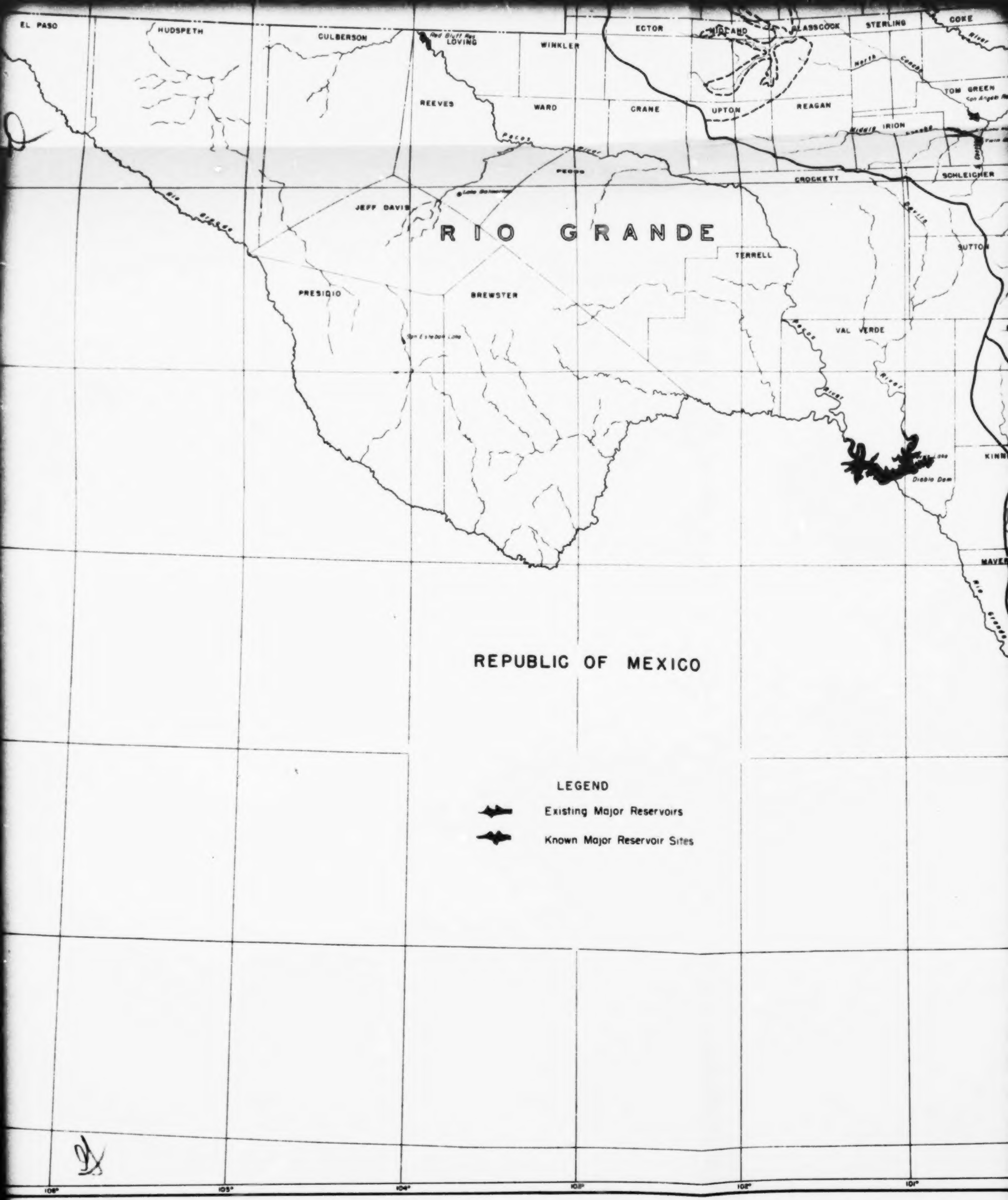


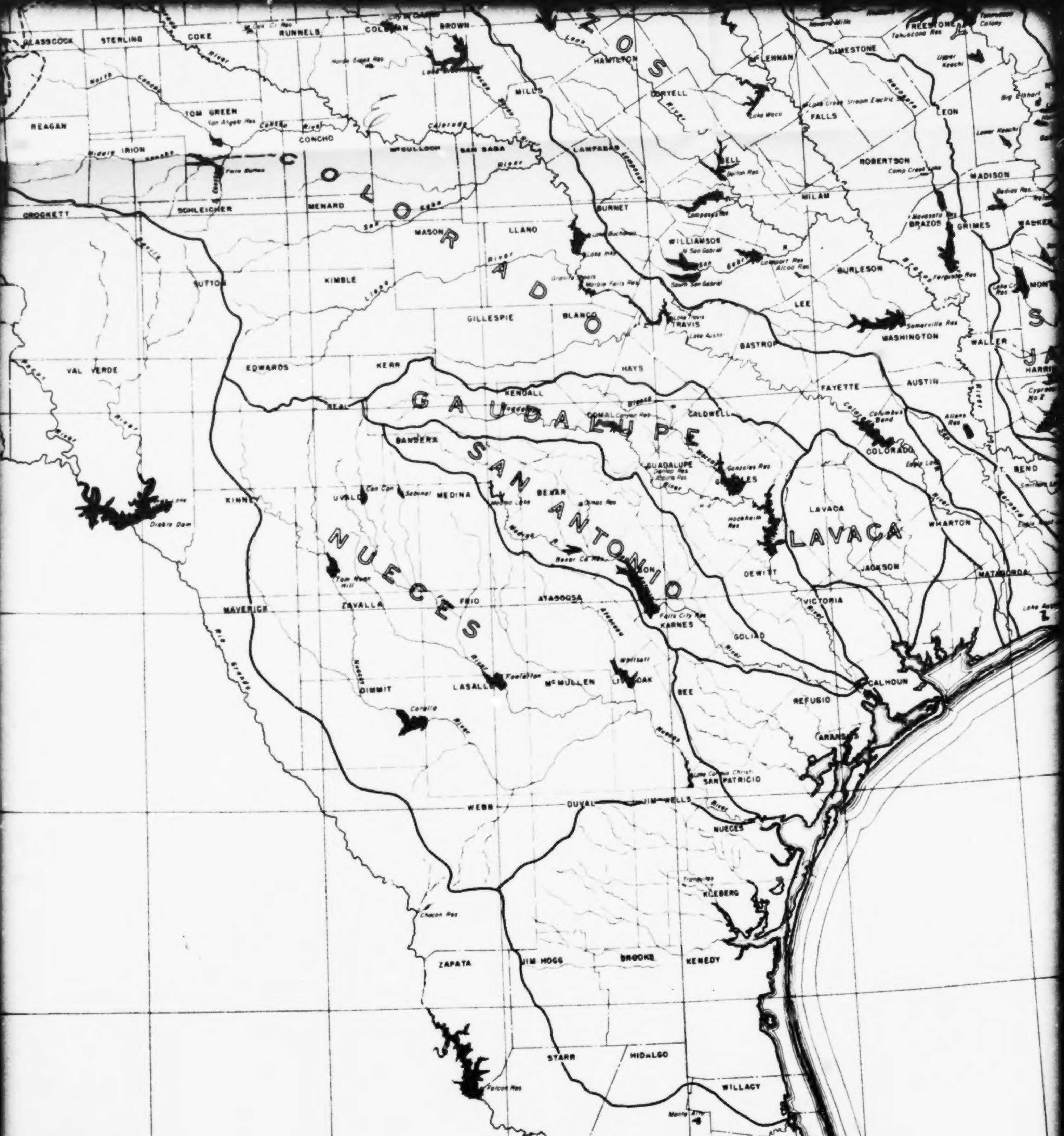
OKLAHOMA
ARKANSAS
LOUISIANA
B R A Z O S
T R I N I T Y
S A B I N E
N E C H E S
R A D O
S A N
Red River
Wichita River
WICHITA
ARCHER
CLAY
MONTAGUE
COOKE
GRAYSON
Lake Texoma
Lake Randall
FANNIN
LAMAR
RED RIVER
BOWIE
Texarkana Res
CASS
TITUS
FRANKLIN
MORRIS
HOPKINS
DELTA
HUNT
COLLIN
DENTON
WISE
JACK
YOUNG
THROCKMORTON
Lake Kickapoo
Lake Wichita
Amon Carter
Lake Bridgeport
Eagle Mountain Lake
Grapevine Res
Lavon Res
Possum Kingdom Res
STEPHENS
PALO PINTO
PARKER
TARRANT
DALLAS
ROCKWALL
KAUFMAN
RAINS
WOOD
CAMP
UPSHUR
MARION
Caddo Lake
HARRISON
VAN ZANDT
SMITH
GREGG
RUSK
PANOLA
EASTLAND
ERATH
HOOD
SOMERVELL
JOHNSON
ELLIS
NAVARRO
HENDERSON
CHEROKEE
HILL
BOSQUE
COMANCHE
BROWN
HAMILTON
MILLS
CORYELL
McLENNAN
LIMESTONE
FREESTONE
ANDERSON
NACOGDOCHES
SHELBY
SAN AUGUSTINE
SABINE
Toledo Bend
HOUSTON
ANGELINA
TRINITY
LEON
FALLS
ROBERTSON
Lake Waco
BELL
Belton Res
LAMPASAS
SAN SABA
BURNET
Lake Buchanan
LLANO
MILAM
WILLIAMSON
BURLESON
BRAZOS
MADISON
GRIMES
WALKER
SAN JACINTO
POLK
TYLER
JASPER
NEWTON
HARDIN
MONTGOMERY
LIBERTY
ORANGE
LEE
TRAVIS
BLANCO
GILLESPIE
Lake Livingston Site
Lake Travis


NEW MEXICO
R E
COCHRAN
HOCKLEY
LUBBOCK
CROSBY
DICKENS
KING
White River Mun W.D.
YOAKUM
TERRY
LYNN
GARZA
KENT
STONEWALL
Double Mountain Fork
Salt Fork
GAINES
DAWSON
BORDEN
SCURRY
FISHER
Lake J.B. Thomas
ANDREWS
MARTIN
HOWARD
MITCHELL
NOLAN
Lake Colorado City
Lake Sweetwater
Champion Creek Res
Colorado River
EL PASO
HUDSPETH
CULBERSON
Red Bluff Res
LOVING
WINKLER
ECTOR
MIDLAND
GLASSCOCK
STERLING
COKE
North Concho
REEVES
WARD
CRANE
UPTON
REAGAN
TOM GREEN
San Angelo Res
Middle IRION Concho
Lake Nasworthy
Twin Buttes
Pecos River
PECOS
CROCKETT
SCHLEICHER
Lake Balmorhea
JEFF DAVIS
Devils
RIO GRANDE
TERRELL
SUTTON
PRESIDIO
BREWSTER
San Esteban Lake
VAL VERDE
EDWARDS
Pecos River
River
Amistad Lake
Diablo Dam
KINNEY
Rio Grande
MAVERICK
Rio Grande
REPUBLIC OF MEXICO
LEGEND
Existing Major Reservoirs
Known Major Reservoir Sites

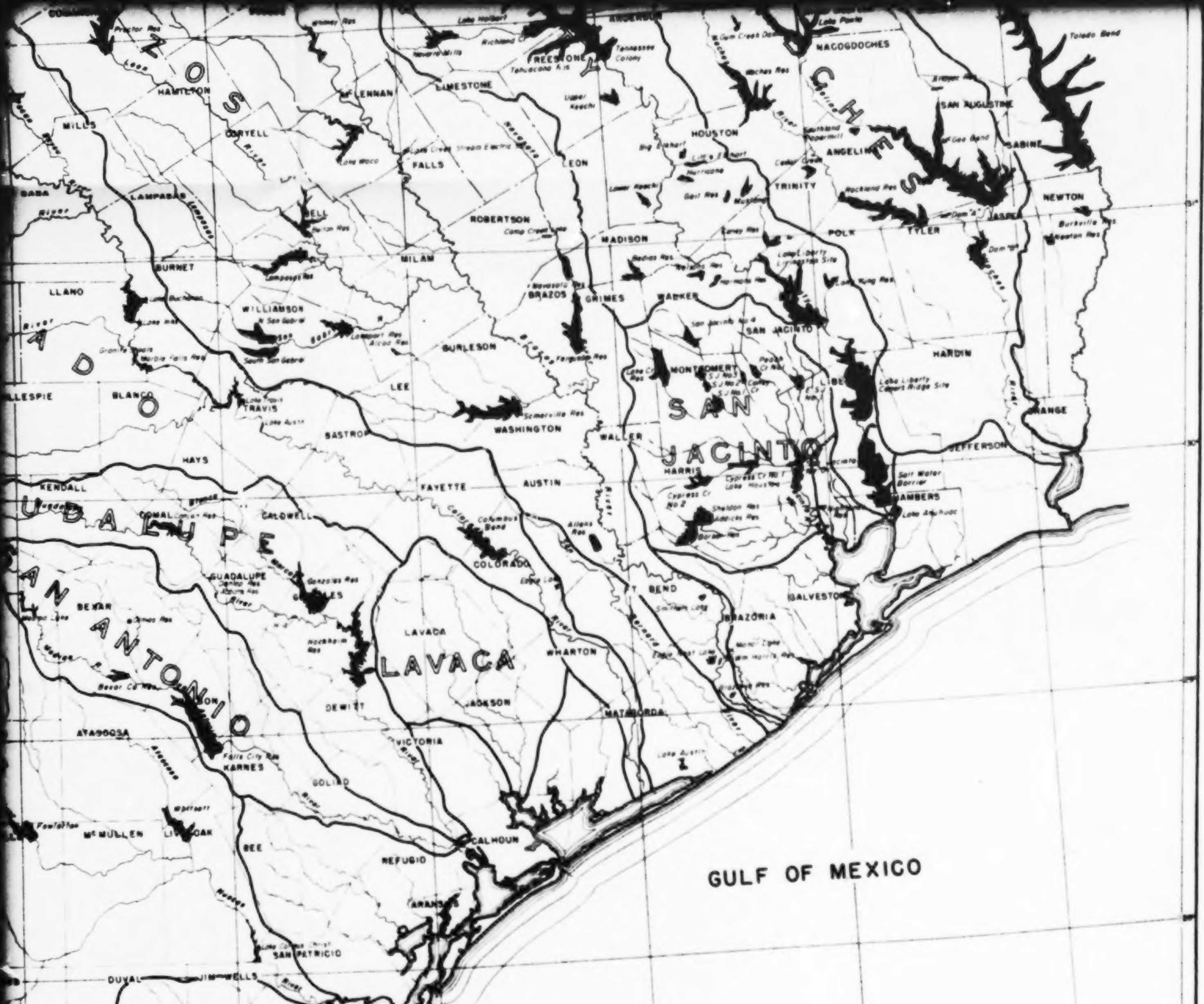

RED
BRAZOS
COLORADO
RANDE
GAUDALUPE
SAN ANTONIO
NUECES
LAVAC
MEXICO
BAILEY
LAMB
HALE
FLOYD
Lake Pauline
HARDEMAN
COTTLE
FOARD
WILBARGER
WICHITA
Red River
Pease River
Wichita River
Santa Rosa Lake
Lake Wichita
Lake Kemp
Lake Kickapoo
COCHRAN
HOCKLEY
LUBBOCK
CROSBY
DICKENS
KING
KNOX
BAYLOR
ARCHER
CLAY
MONTAGUE
COOKE
White River Mun W D
YOAKUM
TERRY
LYNN
GARZA
KENT
STONEWALL
HASKELL
THROCKMORTON
YOUNG
JACK
WISE
DENTON
Salt Fork
Double Mountain Fork Res
Lake Stamford
Breckenridge Res
Lake Eddleman
South Bend
Lake Bridgeport
Eagle Mountain Lake
GAINES
DAWSON
BORDEN
SCURRY
FISHER
JONES
SHACKELFORD
STEPHENS
PALO PINTO
PARKER
TARRANT
DALLAS
Lake J B Thomas
Hubbard Creek Dam
Lake Daniel
Fort Phantom Hill Res
Lake Weatherford
Lake Worth
Benbrook Res
ANDREWS
MARTIN
HOWARD
MITCHELL
Lake Colorado City
NOLAN
Lake Sweetwater
TAYLOR
CALLAHAN
EASTLAND
Lake Cisco
Lake Leon
ERATH
HOOD
JOHNSON
ELLIS
De Cordova Bend Res
Lake Abilene
Kirby Lake
Champion Creek Res
ECTOR
MIDLAND
GLASSCOCK
STERLING
COKE
RUNNELS
COLEMAN
BROWN
COMANCHE
SOMERVELL
BOSQUE
HILL
Proctor Res
Whitney Res
CRANE
UPTON
REAGAN
TOM GREEN
San Angelo Res
Concho River
Lake Brownwood
Hords Creek Res
HAMILTON
MILLS
CORYELL
McLENNAN
Lake Waco
LIMESTONE
IRION
CONCHO
McCULLOCH
SAN SABA
Lake Nasworthy
Twin Buttes
LAMPASAS
FALLS
BELL
Belton Res
CROCKETT
SCHLEICHER
MENARD
MASON
LLANO
BURNET
Lake Buchanan
Lampasas Res
MILAM
WILLIAMSON
N San Gabriel
South San Gabriel
Laneport Res
TERRELL
SUTTON
KIMBLE
Granite Shoals
Marble Falls Res
BURLESON
GILLESPIE
BLANCO
TRAVIS
Lake Travis
Lake Austin
LEE
VAL VERDE
EDWARDS
KERR
HAYS
BASTROP
REAL
KENDALL
COMAL
Canyon Res
FAYETTE
BANDERA
CALDWELL
KINNEY
UVALDE
Con Can
Sabinal
MEDINA
BEXAR
Medina Lake
GUADALUPE
GONZALES
Gonzales Res
Amistad Lake
Diablo Dam
Devils River
Pecos River
Cloptin Res
Hochheim Res
LAVACA
DEWITT
Tom Nunn Hill
Bexar Co Res
MAVERICK
ZAVALLA
FRIO
ATASCOSA
WILSON
KARNES
Falls City Res
VICTORIA
GOLIAD
JACKSON
Rio Grande
Nueces River
DIMMIT
LASALLE
Fowlerton
McMULLEN
LIVE OAK
Whitsett
Cotulla
BEE
REFUGIO
CALHOUN
ARANSAS
Lake Corpus Christi
SAN PATRICIO
WEBB
DUVAL
JIM WELLS
NUECES
Reservoirs
rvoir Sites


ARKANSAS
LOUISIANA
GULF OF MEXICO
BRAZOS
TRINITY
SABINE
NECHES
SAN JACINTO
LAVACA
COLORADO
GUADALUPE
SAN ANTONIO
Wichita
ARCHER
CLAY
MONTAGUE
N. Montague Co. W.S.D.
Lake Kickapoo
COOKE
Lake Randall
GRAYSON
FANNIN
Lake Coffee Mill
LAMAR
Lake Crook
RED RIVER
Red River
BOWIE
Texarkana Res
River Crest Electric
Sulphur
CASS
TITUS
MORRIS
FRANKLIN
DELTA
Cooper Res
HOPKINS
HUNT
COLLIN
DENTON
WISE
JACK
YOUNG
THROCKMORTON
Amon Carter
Lake Bridgeport
Salt Cr Dam
Lake Eddleman
South Bend
Eagle Mountain Lake
Lavon Res
Grapevine Res
PALO PINTO
STEPHENS
PARKER
TARRANT
DALLAS
ROCKWALL
North Lake Steam Electric Station
Forney Res
RAINS
WOOD
Lake Fork Res
Big Sandy Res
CAMP
UPSHUR
Ellison Creek Res
MARION
Ferrells Bridge Res
Mooringsport Res
Caddo Lake
HARRISON
KAUFMAN
Terrell Municipal Res
VAN ZANDT
Lake Worth
Benbrook Res
Hubbard Creek Dam
EASTLAND
ERATH
HOOD
JOHNSON
ELLIS
SMITH
GREGG
Lake Gladewater
Lake Cherokee
Martin Res
Carthage Res
Eight Mile Res
De Cordova Bend Res
Squaw Creek Res
SOMERVELL
HILL
NAVARRO
HENDERSON
Lake Tyler
Henderson Res
CHEROKEE
Murvaul Bayou Res
COMANCHE
Proctor Res
BOSQUE
Lake Trinidad
Lake Halbert
Richland Cr
Navarro Mills
ANDERSON
Blackburn Crossing
Striker Creek Dam
Lake Ponta
Gum Creek Dam
NACOGDOCHES
SHELBY
Toledo Bend
BROWN
Lake Brownwood
HAMILTON
FREESTONE
Tehuacana Res
Tennessee Colony
MILLS
CORYELL
McLENNAN
LIMESTONE
Upper Keechi
Lake Waco
Lake Creek Steam Electric Station
FALLS
LEON
HOUSTON
Big Elkhart
Little Elkhart
Hurricane
Lower Keechi
Gail Res
Mustang
Southland Paper mill
SAN AUGUSTINE
McGee Bend
ANGELINA
SABINE
TRINITY
Rockland Res
POLK
TYLER
Dam "A"
JASPER
NEWTON
Burkville Res
Newton Res
Dam "B"
SAN SABA
LAMPASAS
BELL
Belton Res
Lampasas Res
BURNET
LLANO
ROBERTSON
Camp Creek Lake
MADISON
Bedias Res
Coney Res
Lake Liberty
Livingston Site
Lake King Res
MILAM
WILLIAMSON
N San Gabriel
South San Gabriel
Laneport Res
Alcoa Res
Buchanan
Granite Shoals
Marble Falls Res
BRAZOS
Navasota Res
GRIMES
WALKER
SAN JACINTO
BURLESON
Ferguson Res
HARDIN
GILLESPIE
BLANCO
Lake Travis
TRAVIS
Lake Austin
LEE
Somerville Res
WASHINGTON
MONTGOMERY
SJ No 3
SJ No 2
SJ No 1
LIBERTY
Lake Liberty
Capers Ridge Site
ORANGE
BASTROP
HAYS
KENDALL
WALLER
HARRIS
Cypress Cr No 1
Lake Houston
Cypress Cr No 2
Sheldon Res
Addicks Res
Barker Res
JEFFERSON
Salt Water Barrier
CHAMBERS
Lake Anahuac
COMAL
Canyon Res
CALDWELL
FAYETTE
AUSTIN
Columbus Bend
Allens Res
COLORADO
GUADALUPE
Gonzales Res
GONZALES
Hochheim Res
BEXAR
MEDINA
Medina Lake
Bexar Co Res
LAVACA
FT BEND
Smithers Lake
GALVESTON
BRAZORIA
Eagle Nest Lake
WHARTON
DEWITT
JACKSON
WILSON
FRIO
ATASCOSA
Falls City Res
KARNES
GOLIAD
VICTORIA
MATAGORDA
Lake Austin
LASALLE
Fowlerton
McMULLEN
LIVE OAK
BEE
REFUGIO
CALHOUN
ARANSAS
Lake Corpus Christi
SAN PATRICIO
WEBB
DUVAL
JIM WELLS
NUECES
KLEBERG
GRAPHIC SCALE
10 0 10 20 30 40 50 60 70


EL PASO
HUDSPETH
CULBERSON
Red Bluff Res
LOVING
WINKLER
ECTOR
MIDLAND
GLASSCOCK
STERLING
COKE
REEVES
WARD
CRANE
UPTON
REAGAN
TOM GREEN
San Angelo Res
IRION
Pecos River
PECOS
Lake Balmorhea
JEFF DAVIS
CROCKETT
SCHLEICHER
SUTTON
RIO GRANDE
TERRELL
PRESIDIO
BREWSTER
San Esteban Lake
VAL VERDE
Pecos River
Devils River
Diablo Dam
KINN
MAVER
Rio Grande
REPUBLIC OF MEXICO
LEGEND
Existing Major Reservoirs
Known Major Reservoir Sites
106°
105°
104°
103°
102°
101°


COLORADO
GAUDALUPE
SAN ANTONIO
NUECES
LAVACA
GLASSCOCK
STERLING
COKE
RUNNELS
COLEMAN
BROWN
HAMILTON
McLENNAN
LIMESTONE
FREESTONE
REAGAN
TOM GREEN
CONCHO
MILLS
CORYELL
FALLS
LEON
IRION
McCULLOCH
SAN SABA
LAMPASAS
BELL
ROBERTSON
MADISON
CROCKETT
SCHLEICHER
MENARD
BURNET
MILAM
MASON
LLANO
WILLIAMSON
BRAZOS
GRIMES
WALKER
SUTTON
KIMBLE
BURLESON
GILLESPIE
BLANCO
TRAVIS
LEE
WASHINGTON
WALLER
VAL VERDE
EDWARDS
KERR
HAYS
BASTROP
FAYETTE
AUSTIN
HARRIS
KENDALL
REAL
COMAL
CALDWELL
BANDERA
COLORADO
UVALDE
MEDINA
BEXAR
GUADALUPE
GONZALES
KINNEY
LAVACA
WHARTON
DEWITT
JACKSON
MATAGORDA
FT. BEND
FRIO
ATASCOSA
KARNES
VICTORIA
MAVERICK
ZAVALLA
GOLIAD
CALHOUN
DIMMIT
LASALLE
McMULLEN
LIVE OAK
BEE
REFUGIO
ARANSAS
SAN PATRICIO
WEBB
DUVAL
JIM WELLS
NUECES
KLEBERG
ZAPATA
JIM HOGG
BROOKS
KENEDY
STARR
HIDALGO
WILLACY
CAMERON
Lake Waco
Belton Res
Lake Buchanan
Marble Falls Res
Lake Travis
Lake Austin
Somerville Res
Columbus Bend
Canyon Res
Gonzales Res
Hockheim Res
Amistad Res
Diablo Dam
Tom Nunn Hill
Bexar Co Res
Falls City Res
Foutetton
Cotulla
Lake Corpus Christi
Chacon Res
Falcon Res
Hidalgo Co WCBID 6
Valley Acres
Monte Alto
Brownsville Navigation District
Ferguson Res
Camp Creek Lake
Navasota Res
Tehuacana Res
Tennessee Colony
South San Gabriel
N San Gabriel
Laneport Res
Alcoa Res
Lampasas Res
San Angelo Res
Twin Buttes
101°
100°
99°
98°
97°

H


BRAZOS
NECHES
COLORADO
GUADALUPE
SAN ANTONIO
LAVACA
SAN JACINTO
GULF OF MEXICO
HAMILTON
MILLS
CORYELL
McLENNAN
LIMESTONE
FREESTONE
ANDERSON
NACOGDOCHES
SAN AUGUSTINE
SABINE
FALLS
LEON
HOUSTON
ANGELINA
TRINITY
NEWTON
LAMPASAS
BELL
ROBERTSON
MADISON
POLK
TYLER
JASPER
BURNET
MILAM
LLANO
WILLIAMSON
BRAZOS
GRIMES
WALKER
SAN JACINTO
HARDIN
BURLESON
MONTGOMERY
LIBERTY
BLANCO
TRAVIS
LEE
WASHINGTON
WALLER
ORANGE
BASTROP
HAYS
HARRIS
JEFFERSON
KENDALL
FAYETTE
AUSTIN
CHAMBERS
COMAL
CALDWELL
GUADALUPE
GONZALES
COLORADO
FT BEND
BEXAR
LAVACA
WHARTON
BRAZORIA
GALVESTON
DEWITT
JACKSON
MATAGORDA
ATASCOSA
KARNES
VICTORIA
GOLIAD
McMULLEN
LIVE OAK
BEE
REFUGIO
CALHOUN
ARANSAS
SAN PATRICIO
DUVAL
JIM WELLS
NUECES
KLEBERG
JIM HOGG
BROOKS
KENEDY
STARR
HIDALGO
WILLACY
CAMERON
GRAPHIC SCALE
SCALE IN MILES
1" = Approximately 40 miles

STATE OF TEXAS

BOARD OF WATER ENGINEERS
AUSTIN, TEXAS

SURFACE WATER RESERVOIRS

DEC. 1958	PLATE X 3	TWRP-4

346l

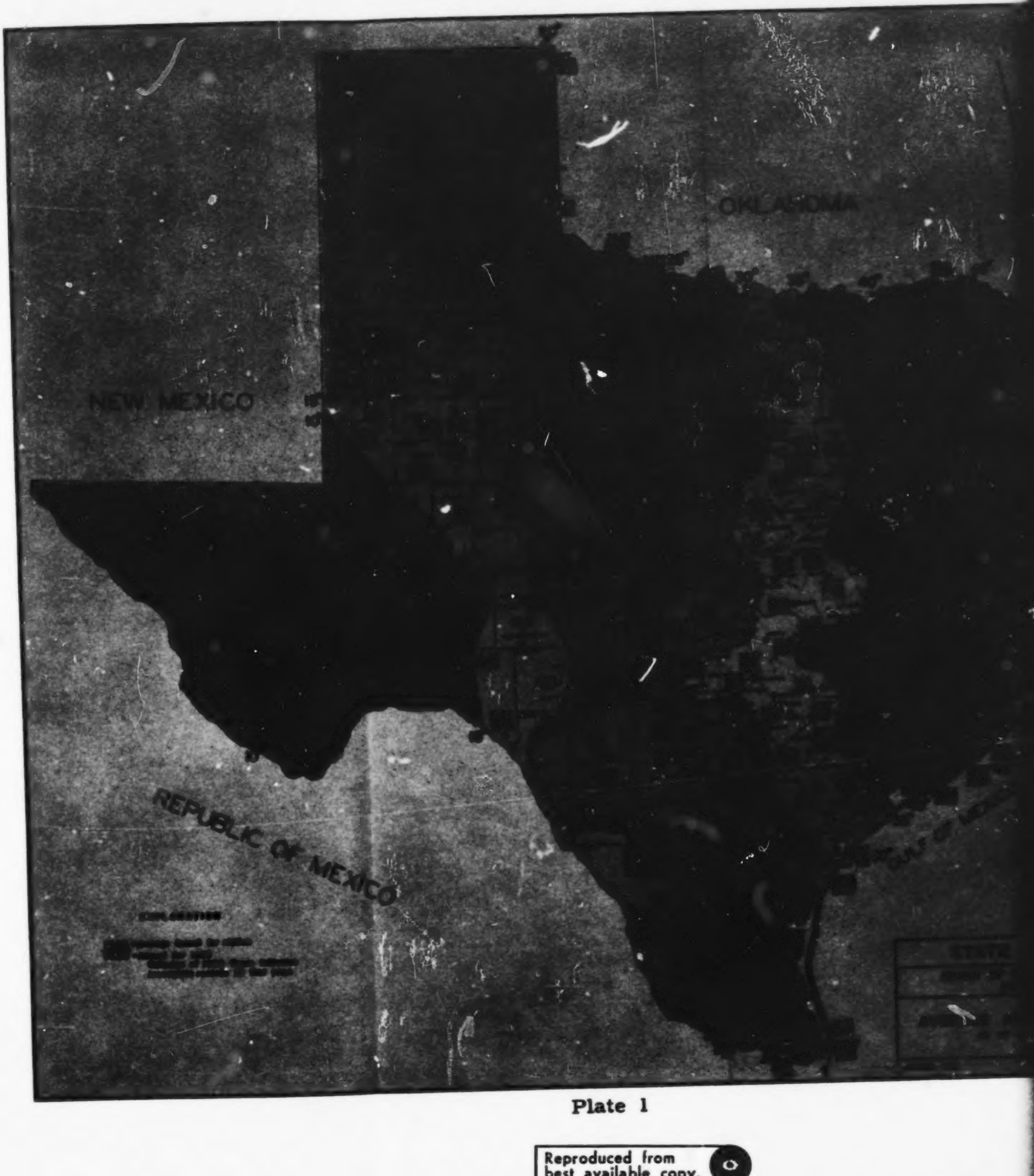

NEW MEXICO
OKLAHOMA
REPUBLIC OF MEXICO
GULF OF MEXICO
EXPLANATION

Plate 1

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346l

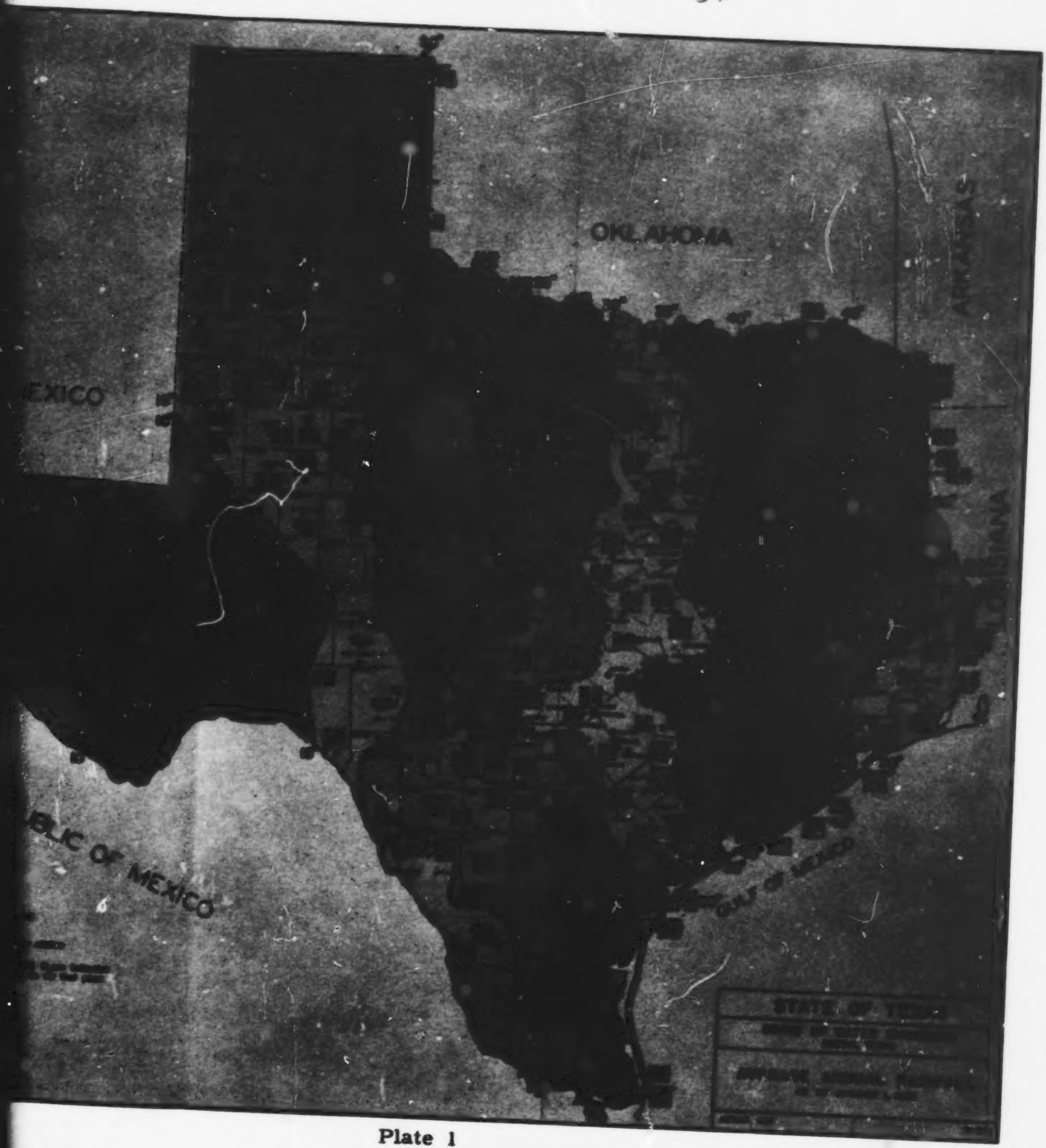
OKLAHOMA
ARKANSAS
EXICO
LOUISIANA
BLIC OF MEXICO
GULF OF MEXICO
STATE OF TEXAS

Plate 1

63198 O - 61 (Face p. 347) No. 1

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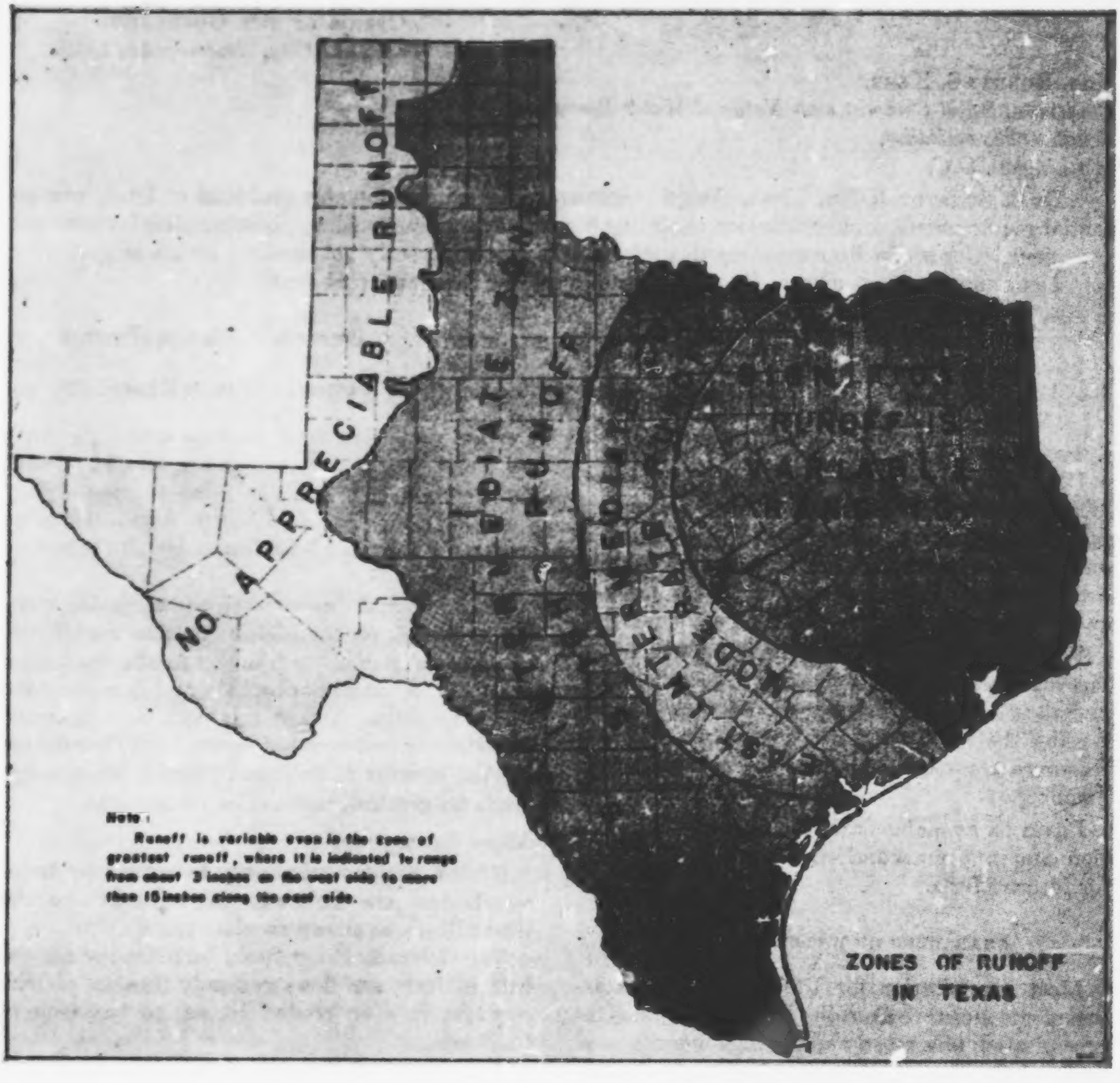
PLATE 2


NO APPRECIABLE RUNOFF
INTERMEDIATE ZONE OF RUNOFF
MODERATE
RUNOFF IS VARIABLE

Note:

Runoff is variable even in the zone of greatest runoff, where it is indicated to range from about 3 inches on the west side to more than 15 inches along the east side.

ZONES OF RUNOFF IN TEXAS
]

UTAH

STATE OF UTAH,
OFFICE OF THE GOVERNOR,
Salt Lake City, December 23, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
Senate Office Building,
Washington, D.C.

DEAR SENATOR KERR: The attached statement concerning the water problems of Utah, our potential requirements, and conclusions regarding a solution to these problems, is submitted for your use.

Your letter originally requesting this information was apparently not received by my office.

Again may I commend you for your efforts to resolve our water problems.

Very truly yours,

GEORGE D. CLYDE, *Governor.*

UTAH STATEMENT TO THE U.S. SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES

INTRODUCTION

Utah, like her sister States of the arid West, faces a great challenge. To provide for an expanding population and unlock the treasure of vast natural resources, it is imperative that we utilize with more efficiency present water supplies and develop new sources.

Future water requirements can only be met by a vigorous and comprehensive approach. Careful, overall studies and more basic information concerning the extent and occurrence of our water resources are vital necessities for comprehensive planning.

Based on available data, the following information and recommendations are given as guides for future efforts.

CHARACTER OF WATER SUPPLIES

Most precipitation for Utah is carried as atmospheric moisture from the Pacific Ocean. This precipitation falls mostly on the high mountainous areas of the State. Because of our inland position, separated from the ocean by numerous high mountain masses to the west, our total supply is low. It is estimated that the average for the entire State is only 11.5 inches, as compared to 30 inches for the Nation.

Wide variations from average are the general rule, and yearly fluctuations are erratic. Much precipitation comes in the form of snow during the winter months—October to April. Growing season precipitation is far from adequate to supply crop needs.

As the annual warm season advances, the melting snowpack on the high mountains contributes to the streams of water which generally reach their greatest magnitude during May and June and then decline rapidly. Unless this peak flow is stored in surface or underground reservoirs for use during the hot months of July and August, when water needs are greatest, much of its value is lost.

Major drainage basins

Utah is divided principally between two drainage basins—the Colorado River Basin and the Great Basin, as shown on plate 1.

The Colorado River Basin occupies the eastern half of Utah, and flows generally through plateau country, in deep eroded gorges, to the Gulf of California.

The Great Basin is an interior drainage with no outlet to the ocean. It is made up of a great number of smaller basins and occupies, in general, the west half of the State.

A small area in the northwest part of Utah lies in the Columbia River drainage basin. Utah's

division of area among drainage basins is approximately as follows:

	Percent
Colorado	48.0
Great Basin	51.5
Columbia	0.5

The two major hydrologic units are separated from each other by the Wasatch Mountains and the high plateaus of Utah which traverse, in a north-south direction, the central part of the State.

Colorado River drainage

In the Colorado River drainage basin, the land surface is highly dissected bedrock with deep steep-sided canyons. The major streams are often several hundred feet below the general surface of the land. Much of the water reaching the surface streams has flowed on out of the State toward the sea, rather than into the ground and retained locally. Possible surface reservoir sites are geologically numerous, although economical storage reservoir locations at sites where the water can be readily used are difficult to find. Large dams are required to control the rivers.

A considerable portion of the waters of the Colorado River drainage are developed in Utah and the Upper Basin States. The calculated virgin flow of the Colorado River at Lees Ferry averages some 15,590,000 acre-feet annually. Utah ultimately hopes to deplete the flow of the river about 1,750,000 acre-feet annually. At the present time it is estimated that 650,000 acre-feet are being consumed in this basin in Utah. Our knowledge of the surface flows of the Colorado River Basin is fairly good. Many measurements of the resources are available on the major water contributors, although measurements of the small tributaries are limited. The effects of potential development on stream depletion are still somewhat unknown.

Great Basin

In the Great Basin portion of the State, the areas is made up of short, north-south mountain bedrock masses with small basins of loose valley fill. The mountain streams discharge onto the habitable, flat, valley portions and either disappear into the valley fill or terminate into ephemeral or permanent lakes from which the water is evaporated back into the atmosphere. Few suitable sites for constructing large reservoirs are found in the major canyons, due to the steepness of the slopes.

The potentialities of using the valley fill as an underground reservoir are still unexplored. Seemingly, large quantities of water are naturally recharged to the underground every year. This apparently contributes to our large areas of alkali flats, swamps, and lakes, which annually discharge to the atmosphere tremendous volumes of water. What the effect of controlled draft and controlled recharge of the underground supply will be over our large areas is as yet undetermined. In certain isolated valley localities where overdrafts have already occurred, such as the Escalante Valley (part of Iron and Beaver Counties), close inspection is being maintained.

The total quantities of surface and ground water in the Great Basin area are generally unknown or difficult to define.

Many short and intermittent streams which individually account for little, but collectively may be of considerable importance, are generally unmeasured and run to waste or into the ground without control. The larger streams, all originating and contained within the immediate area of the Wasatch Front, are heavily used and reused. Considerable return flows from irrigated land and sewage discharge occur, so that a single figure of total virgin flow is now difficult to develop by direct measurement.

Although several studies are currently underway, our ground-water information is far from adequate. Investigations have been mostly along the Wasatch Front and have been included only ground-water levels and the geology of the immediate area.

Measurements and estimates are needed of water lost each year through evapotranspiration from open lakes, swamps, and wet areas fed by surface waters and underground sources. This may be a sound method of arriving at what quantities of water are actually available for use in individual basins. It is believed that the quantities of water circulating through the entire Great Basin of Utah are considerable. Large quantities of water are lost from the basin through evapo-transpiration from lake surfaces, marshy and high water table areas, etc. Thus, Utah may still have a great amount of water now consumed in the Great Basin that can ultimately be salvaged and put to a more beneficial use.

Present land and water uses

The irrigated area of the State contains 1,165,000 acres, or 2.1 percent of the total area of the State. Of the total irrigated area, 407,000 acres, or 35 percent, have an adequate water supply, and the remaining 758,000 acres have only a partial supply.

In Utah, 1,429,000 acres of land suitable for agricultural production lie dormant, awaiting a water supply. This land comprises 2.6 percent of the area of the State. As noted on plate 3, over 84 percent of the area of the State is limited to relatively low income grazing.

Plate 4 indicates that less than 5 percent of the total water supply is consumptively used in irrigating the 1,165,000 acres of irrigated cropland, while the evaporation and transpiration of water from the grazing and watershed areas represent three-fourths of the total consumption of the State's water.

Fertile but arid land now used for grazing consumes 2 percent of the State's supply. The income from this land is small, but with an additional water supply to supplement the natural precipitation, production from these areas would constitute a large agricultural potential.

The relentless evaporation from the lakes, streams, and reservoirs of the State constitutes the second largest consumption of water and amounts to 9.5 percent of the total State's supply. The most obvious method of reducing this loss is to more fully utilize the flow of the streams tributary to the Great Salt Lake, since this body alone accounts for an evaporation loss of approximately 3,400,000 acre-feet annually, or 6.5 percent of the State's total water supply.

The runoff which finds its way to the principal streams that leave the State represents 4.3 percent of the State's supply.

Projected requirements

It is common knowledge that the per capita consumption of water is increasing. The combination of expanding population and increased per capita consumption are basic indicators of future needs. Present estimates place the State's population at 881,000 people. This represents an increase of 60 percent over the 1940 population. Over 90 percent of the present population is located in the Great Basin, concentrated along the Wasatch Front, with Salt Lake County accounting for 34 percent of the entire State population. The projected population for 1980 is 1,600,000, or 81.5 percent increase over the present population (see plate 5).

Plate 6 shows Utah's present and 1980 projected water diversion needs. It is estimated that total diversion needs will increase from 5.4 million acre-feet to 7.0 million acre-feet by 1980, or an increase of 29.7 percent.

We expect much more emphasis on an industrial economy, yet agriculture will remain the largest user of water. Irrigation uses are estimated to increase 10 percent while municipal uses increase 150 percent. Manufacturing or industrial uses are likely to increase 400 percent above present levels. Municipal and industrial diversions combined will represent 21.5 percent of the total diversion needs by 1980.

State water development program

The State of Utah has benefited considerably from several Federal reclamation projects located within the State. In addition to these reclamation projects, the State of Utah has, through its own program, assisted in the financing and development of water conservation projects throughout the State where no other means of assistance was available.

Since 1947, 126 water conservation projects, located in 28 of the 29 counties of the State, have been completed, or are under construction, at the present time. The total cost of constructing these projects, as shown on plate 7, is $6,080,158.77. The project sponsors have contributed during the initial construction $1,752,174.43 of the total cost. The balance of $4,327,984.34, has come from a revolving fund replenished by State appropriated funds.

The accomplishments of this program have resulted in an annual saving, or reservoir water yield, of 163,948 acre-feet. Supplemental water for presently irrigated lands has been furnished to 314,604 acres, while 19,435 acres of new land have come under the distribution systems of these projects. The total acreage served amounts to 334,039 acres. The cost of development on an acre-foot basis is $37.09, which is a very reasonable development cost. State funds advanced to these projects are repaid according to the repayment ability of the sponsor. Repayment to the revolving fund is made without interest, although engineering charges incurred by the State in processing and planning the projects are reimbursable costs.

The proof of the value of this project lies in the fact that not one project has failed to meet its annual repayment.

Inventory of potential projects

In cooperation with the U.S. Bureau of Reclamation, the State has recently prepared an inventory of potential water storage projects throughout the State. Plate 8 summarizes the pertinent information gained on this inventory. By 1980, potential projects, both Federal and non-Federal, in the State of Utah, exclusive of the major storage units of the Colorado River storage project, would provide 2,134,000 acre-feet of storage, and would serve 590,000 acres of newly irrigated lands and supplemental lands, or a new land equivalent of 227,644 acres. The estimated average cost per acre-foot of average reservoir yield for non-Federal projects is $73, while Federal projects is $169. We find also that for the period 1980 to the year 2000 there is a potential development of 1,122,686 acre-feet of storage, which would serve a new land equivalent of 218,115 acres. As might be expected, the cost for developing storage in these projects is considerably more than the cost per acre-foot of average yield of the projects developed up to the year 1980. In grand total, to the year 2000, this tabulation would indicate a potential of 112 projects, with an aggregate cost, on present price levels, of $938,836,000, which would provide a water supply for a new land equivalent of 445,759 acres, with total reservoir capacity of 3,256,728 acre-feet.

RECOMMENDATIONS

The solution to the water problems of the State and Nation will require careful and constant study.

To make our efforts more productive it will be necessary to give emphasis to four basic concepts.

1. *The principle of multiple use must be applied to all future developments.*—Water for consumptive uses will have primacy. However, the maximum benefits for fish, wildlife, and recreation must be achieved.

2. *Improved Federal, State and local cooperation is needed.*—Local interests must assume responsibilities commensurate with their abilities. State and Federal assistance should be limited to those projects which are beyond the abilities of local groups. All efforts must be coordinated and all developments in accordance with an overall plan.

3. *It is absolutely imperative that all future developments of water be integrated with the most beneficial overall planning.*—Overall planning will require more basic data and research and a cooperative approach.

4. *Future water developments must be financially assisted by regional accounts.*—By application of this principle, surplus power revenues derived from existing hydroelectric plants would be available to assist in the cost of developing water resources where national interests are benefited, but immediate costs to water users are beyond their ability to pay. This approach would provide for needed additional water by developing our streams from the top down, and also assisting in the desalinization of water in areas where this potential exists.

Plate 1

PRINCIPAL DRAINAGE BASINS

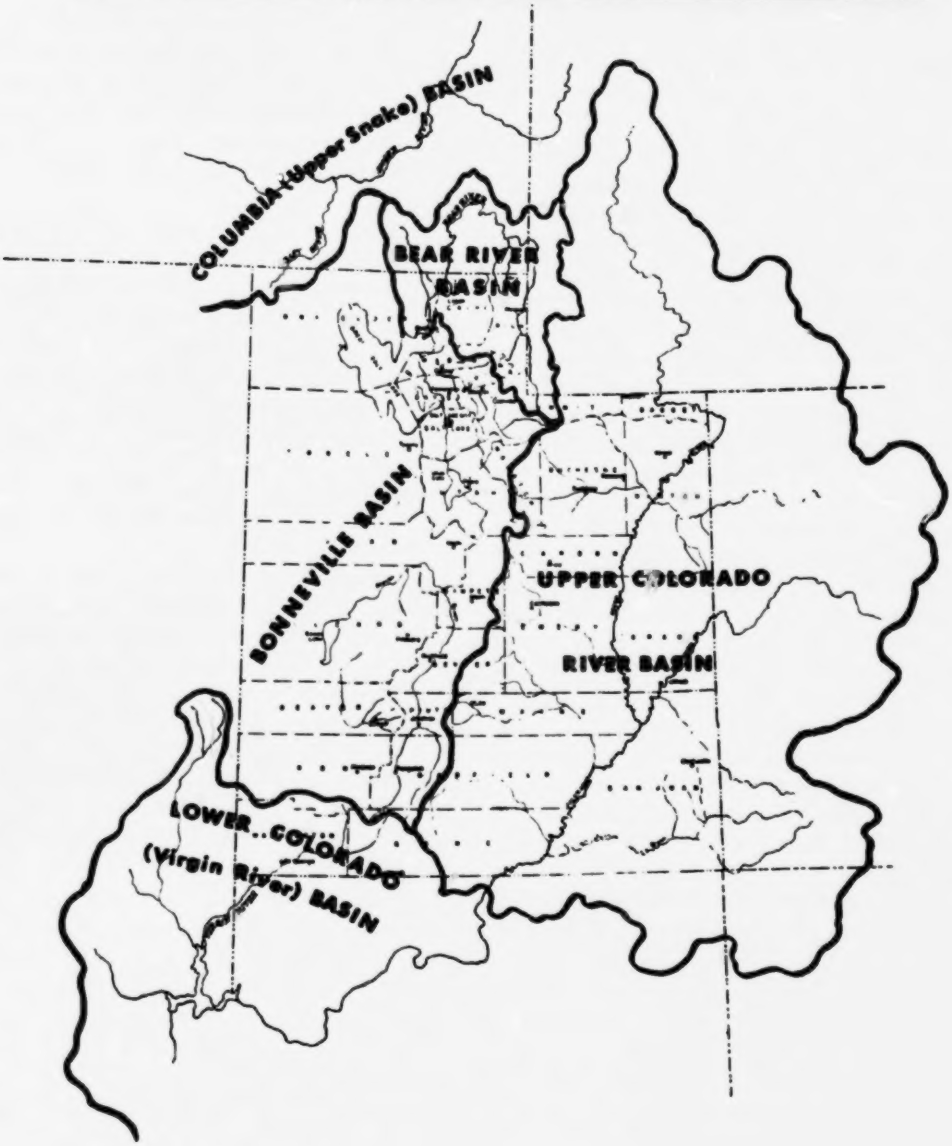

COLUMBIA (Upper Snake) BASIN
BEAR RIVER BASIN
BONNEVILLE BASIN
UPPER COLORADO RIVER BASIN
LOWER COLORADO (Virgin River) BASIN

Plate 2

AVERAGE ANNUAL PRECIPITATION

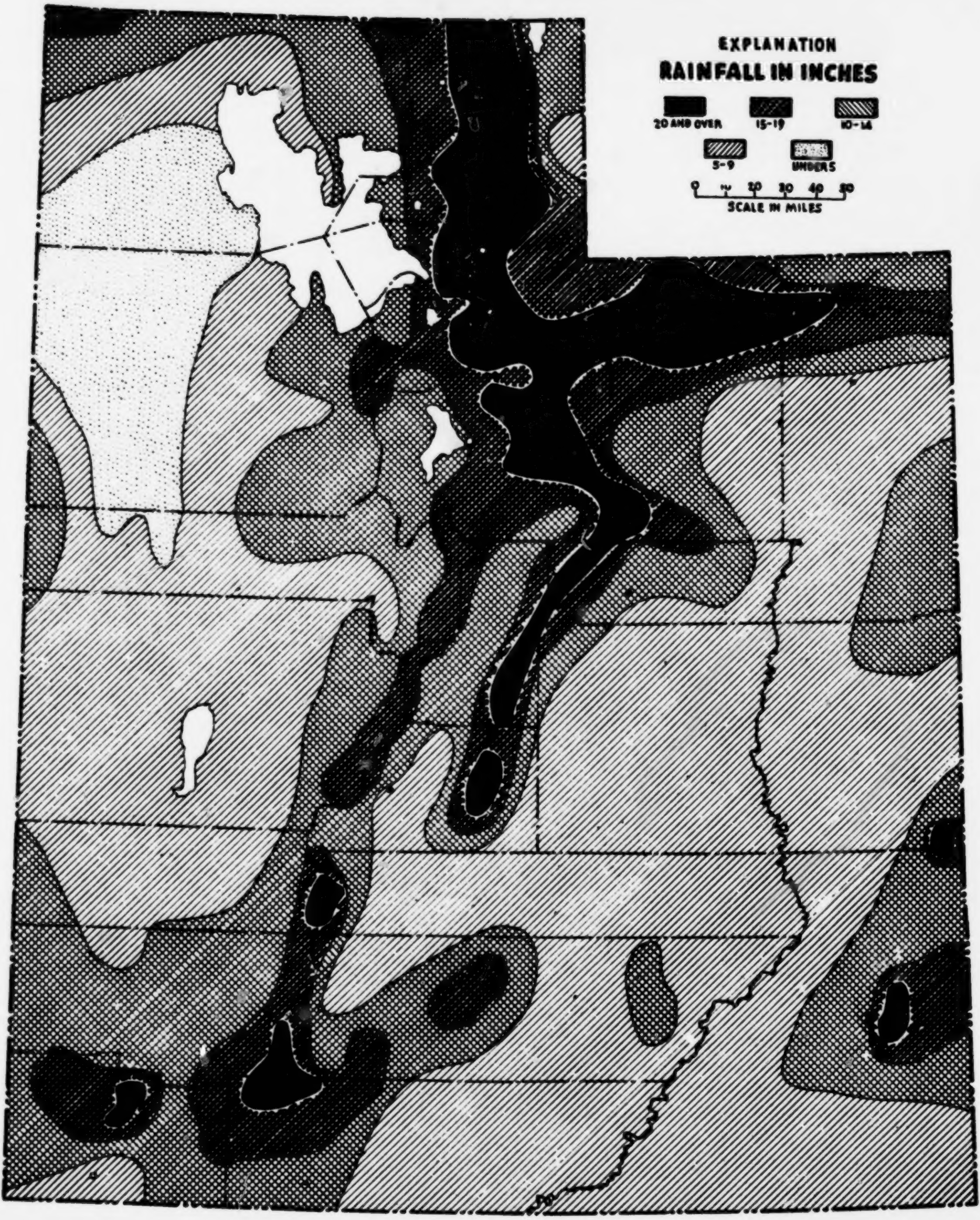

EXPLANATION
RAINFALL IN INCHES
20 AND OVER
15-19
10-14
5-9
UNDER 5
0 10 20 30 40 50
SCALE IN MILES

PLATE 8

TOTAL AREA ACCORDING TO USE, UTAH

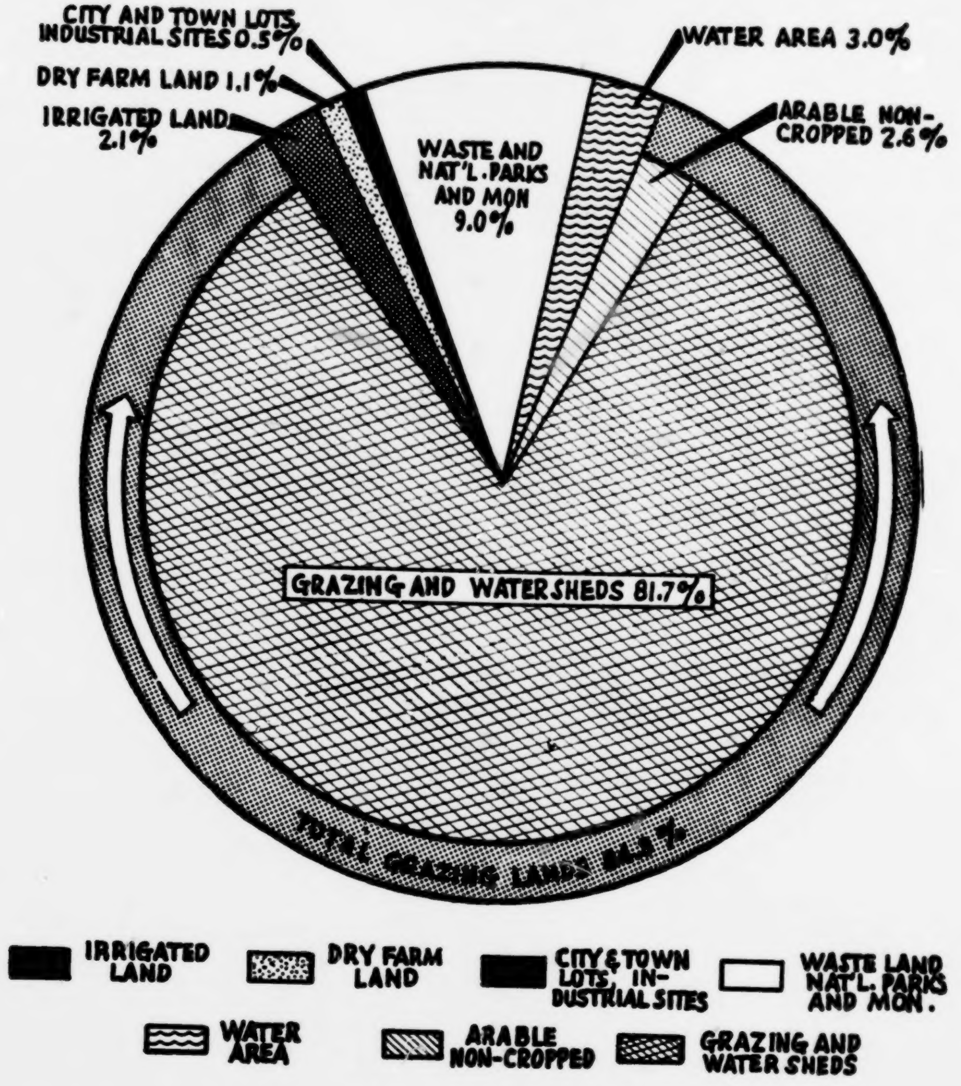


PLATE 4

WATER CONSUMPTION BY AREAS, UTAH

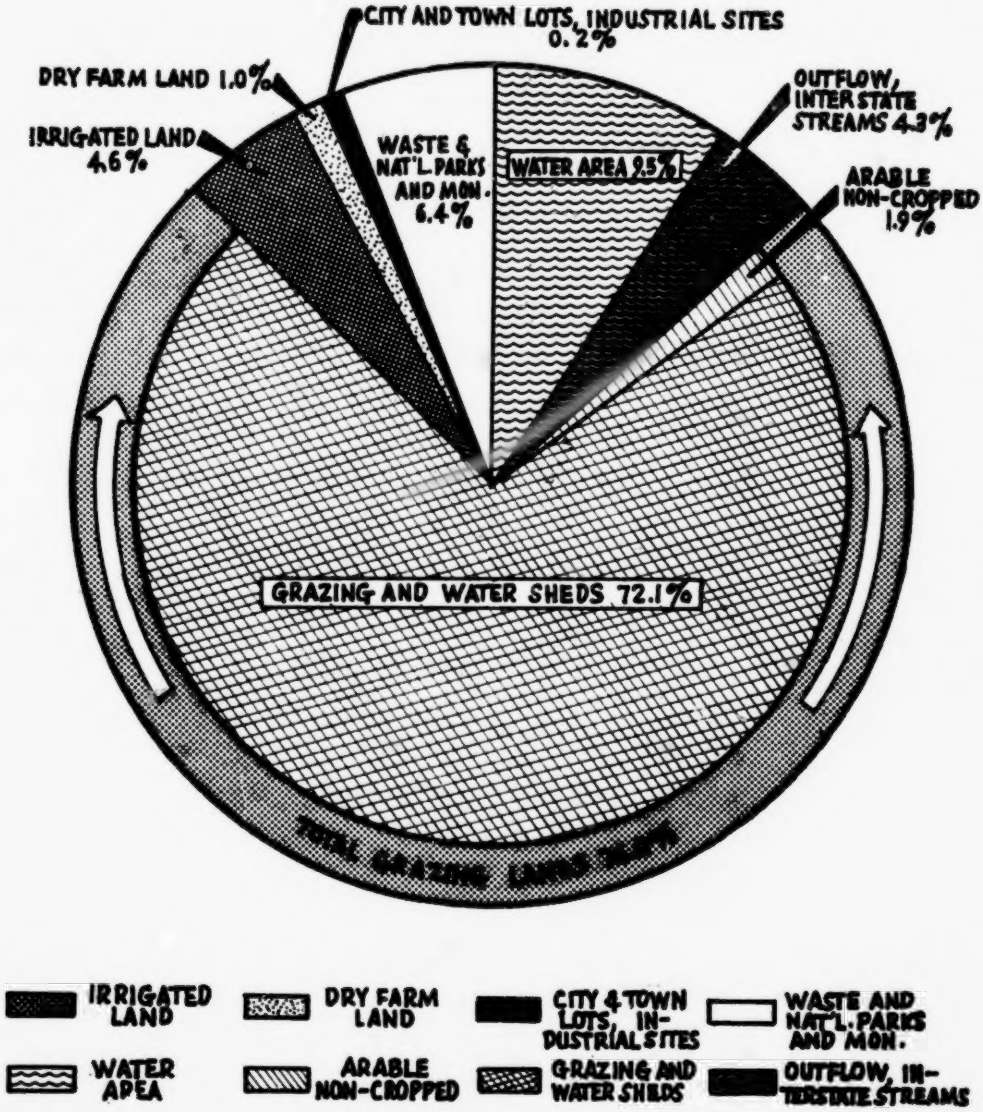


PLATE 5

Utah population

County	1940 [1]	Percent of State	1959 [2]	Percent of State	1980 [3]	Percent of State
Beaver	5,014	0.9	4,600	0.5	5,000	0.3
Box Elder	18,832	3.4	23,500	2.7	44,000	2.8
Cache	29,797	5.4	36,500	4.1	45,000	2.9
Carbon	18,459	3.4	22,500	2.6	42,000	2.5
Daggett	564	.1	1,100	.1	1,500	.1
Davis	15,784	2.8	59,500	6.8	144,000	9.0
Duchesne	8,958	1.6	7,500	.9	8,000	.4
Emery	7,072	1.3	6,000	.7	6,000	.4
Garfield	5,253	1.0	3,500	.5	3,000	.2
Grand	2,070	.4	5,700	.6	11,000	.7
Iron	8,331	1.5	11,000	1.2	16,500	1.0
Juab	7,392	1.3	5,300	.6	5,000	.3
Kane	2,561	.5	3,300	.4	4,500	.3
Millard	9,613	1.7	8,700	.9	9,000	.6
Morgan	2,611	.6	2,900	.3	3,500	.2
Piute	2,203	.5	1,500	.2	1,500	.1
Rich	2,028	.4	1,700	.2	2,000	.1
Salt Lake	211,623	38.4	376,000	42.7	750,000	46.7
San Juan	4,712	.9	8,000	.9	18,000	1.1
Sanpete	16,063	2.9	12,000	1.4	12,000	.8
Sevier	12,112	2.2	11,400	1.2	11,000	.7
Summit	8,714	1.6	5,800	.7	6,000	.4
Tooele	9,133	1.6	17,900	1.9	30,000	1.9
Uintah	9,898	1.8	10,900	1.2	22,000	1.4
Utah	57,382	10.4	108,000	12.3	180,000	11.2
Wasatch	5,754	1.0	5,400	.6	6,000	.4
Washington	9,269	1.7	10,400	1.2	15,000	.9
Wayne	2,394	.4	1,900	.2	2,000	.1
Weber	56,714	10.3	108,500	12.4	200,000	12.5
Total State	550,310	100.0	881,000	100.0	1,600,000 1,603,500	100.0

[1] U.S. Bureau of Census, 1950. "Utah, Number of Inhabitants," p. A44, U.S. Government Printing Office, 1951.

[2] Utah Population Work Committee of Utah, "Committee on Industrial and Employment Planning Newsletter," vol. 6, No. 2, April 1959. Estimate as of Jan. 1, 1959.

[3] A Modification and Extension of the Bureau of Economic and Business Research projection to 1975. "Utah Economic and Business Review," vol. 18, No. 1, January 1958.

PLATE 6

STATE OF UTAH

Present and Projected 1980 Water Diversion Needs

(Millions of Acre Feet Per Year)

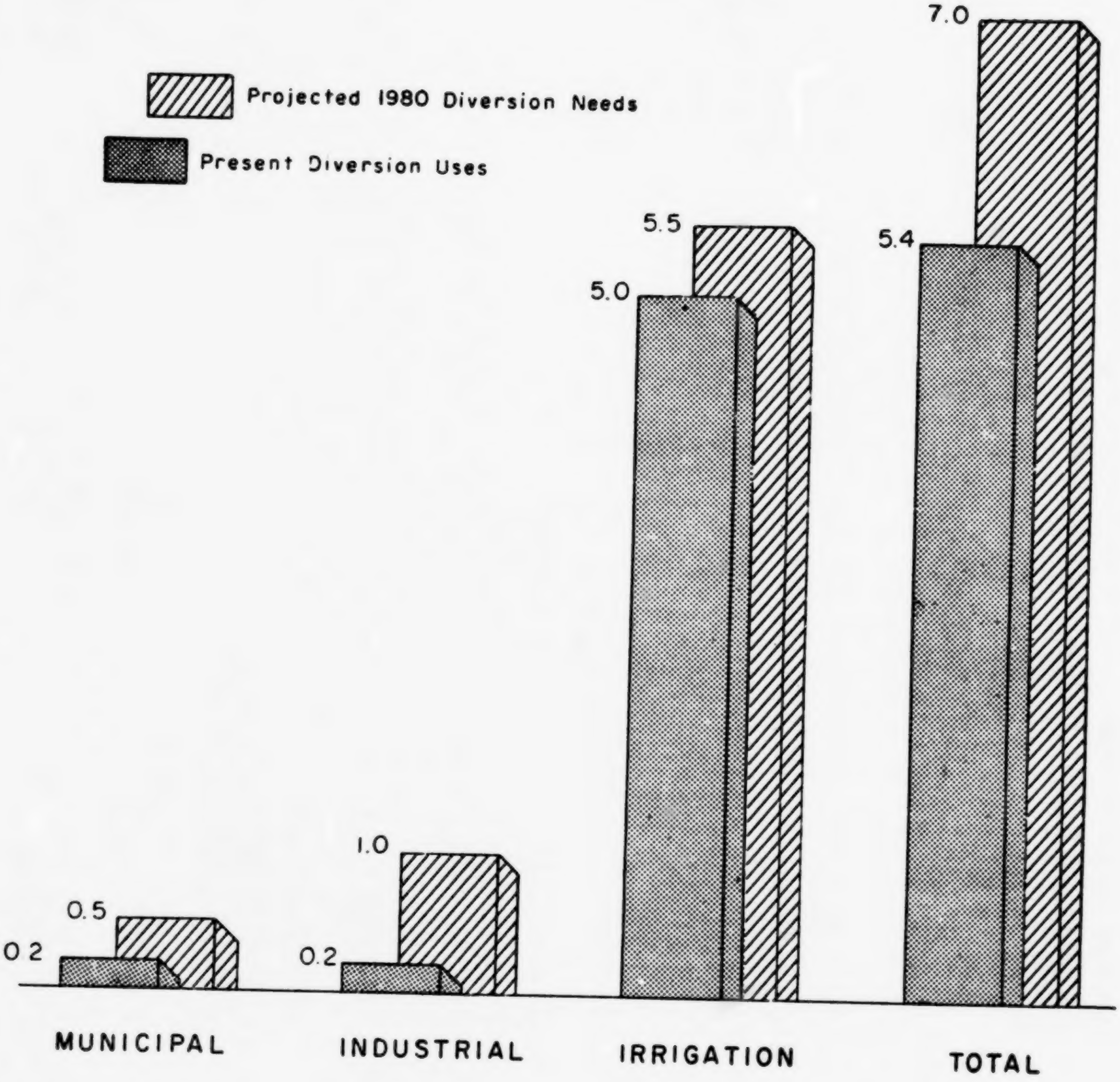


PLATE 7

Utah Water and Power Board—Water conservation projects accomplished May 12, 1947, to Nov. 1, 1959

Project sponsor	Location (county)	Type of project	Project benefits			Project costs		
			Annual water saved or reservoir yield (acre-feet)	Old land (acres)	New land (acres)	Paid by UW&PB	Paid by sponsor	Total cost
1. West Side Irrigation Co.	Beaver	Canal lining	1,000	1,200	----	$17,333.48	$3,012.00	$20,345.48
2. Kents Lake Reservoir Co.	do	Blanketing dam abutments	(See No. 1)	----	----	8,999.60	3,856.97	12,856.57
3. Kents Lake Reservoir Co.	do	Reservoir	2,023	1,400	----	122,147.00	25,000.00	147,147.00
4. Rocky Ford Irrigation Co.	do	Dam repair and canal lining	5,000	7,000	1,000	57,762.56	15,000.00	72,762.56
5. East Grouse Creek Water Co.	Box Elder	Well	225	1,800	----	2,500.00	2,603.00	5,103.00
6. Marble Creek Irrigation Co.	do	Irrigation pipeline	450	600	100	18,793.95	8,054.55	26,848.50
7. Irrigation Co West Fork of Grant Creek.	do	Reservoir	1,300	850	350	100,000.00	52,857.14	152,857.14
8. Blue Creek Irrigation Co.	do	do	2,657	2,654	500	54,000.00	42,786.00	96,780.00
9. South Junction Creek Water Users, Inc.	do	do	410	442	87	36,150.00	16,850.00	53,000.00
10. Evans Water Co.	do	Water system, pipeline	100	60	----	86,659.30	43,592.99	130,252.29
11. Harper Irrigation Co.	do	Canal lining	400	500	----	10,000.00	5,285.71	15,285.71
12. Fisher Creek Irrigation Co.	do	Pipeline	900	875	300	23,000.00	16,379.00	39,379.00
13. Wellsville City Irrigation Co.	Cache	Siphon and canal	90	200	50	3,500.00	3,999.00	7,499.00
14. Richmond Irrigation Co.	do	Well	200	4,230	----	11,250.00	4,821.43	16,071.43
15. Benson-Bear Lake Irrigation Co.	do	Irrigation pipeline	500	(See No. 16)	----	2,741.53	2,649.60	5,391.13
16. Benson-Bear Lake Irrigation Co.	do	do	600	900	100	4,400.00	310.00	4,[illegible]00
17. Logan Northern Canal Co.	do	Canal lining	552	3,600	----	11,583.58	4,964.39	16,547.97
18. Wellington Canal Co.	Carbon	Flume structures	100	2,636	50	3,000.00	2,638.00	5,638.00
19. East Price Water Co.	do	Water supply system	224	1,300	----	25,768.57	11,043.67	36,812.24
20. Wellington Canal Co.	do	Flume structure and siphon	(See No. 18)	----	----	4,485.31	3,825.00	8,310.31
21. Sheep Creek Irrigation Co.	Daggett	Canal enlargement	7,200	5,000	500	20,000.00	8,000.00	28,000.00
22. Kays Creek Irrigation Co.	Davis	Irrigation pipeline	360	3,000	200	8,217.93	1,340.00	9,557.93
23. Laytona Town Corp.	do	Pipeline	540	2,600	100	17,341.34	3,796.00	21,137.34
24. Straight Ditch Co., et al.	do	Irrigation pipeline	1,526	2,360	500	30,507.00	14,801.00	45,308.00
25. Red Creek Irrigation Co.	Duchesne	Reservoir	5,740	1,200	1,500	230,000.00	65,500.00	295,500.00
26. Dry Gulch Irrigation Co.	do	Canal	6,000	5,900	2,000	29,000.00	12,000.00	41,000.00
27. Hidden Valley Irrigation Co.	do	Canals and reservoirs	2,160	----	500	10,500.00	4,500.00	15,000.00
28. Dry Gulch Irrigation Co.	do	Reservoir	1,300	(See No. 26)	----	10,000.00	3,823.00	13,823.00
29. Uintah Basin Irrigation Co.	do	Canals and structure	4,500	6,000	1,500	86,501.48	28,833.82	115,335.30
30. Independent Canal & Reservoir Co.	Emery	Reservoir	725	2,516	500	60,000.00	19,360.00	79,360.00
31. Huntington-Cleveland Irrigation Co.	do	do	2,860	24,470	----	50,668.22	17,979.79	68,648.01
32. McEwan Canal Co.	Garfield	Canal lining and division structure.	500	2,300	----	24,250.00	18,750.00	43,000.00
33. Boulder Irrigation & Water Development Co.	do	Reservoir repair	1,348	2,900	1,000	31,684.70	13,579.16	45,263.86
34. Christensen Ranches, Inc.	do	Pressure irrigation system	1,300	275	350	25,391.14	10,932.45	36,323.59
35. Newcastle Reservoir Co.	Iron	Reservoir	3,000	3,000	----	249,000.00	49,500.00	298,500.00
36. Cedar North Fields Irrigation Co.	do	Canal lining	300	725	----	11,334.71	4,857.75	16,192.44
37. Newcastle Reservoir Co.	do	Dam repair and canal	(See No. 35)	----	----	16,512.26	7,076.68	23,588.94
38. Summit Irrigation Stock Co.	do	Canal lining	300	600	----	12,000.00	5,142.86	17,142.86
39. Spring Creek-LaVerkin Irrigation Co.	do	Reservoir	315	400	50	14,000.00	5,260.00	19,260.00
40. Nephi Irrigation Co.	Juab	Silt control reservoir	----	3,000	----	4,604.14	1,973.20	6,577.34
41. Nephi Irrigation Co.	do	Wells (2)	2,880	(See No. 40)	----	18,370.72	6,747.00	25,117.72
42. Juab Irrigation Co.	do	Canal lining	700	1,000	----	3,000.00	18,500.00	21,500.00
43. Callao Irrigation Co	do	Canal lining and structures	1,400	1,200	500	26,706.90	3,659.00	30,365.90
44. Levan Irrigation Co	do	Flumes and canal lining	1,200	2,500	----	10,013.12	7,433.42	17,446.54
45. Riverbed Irrigation Co.	do	Wells (4) and canal	3,000	1,000	----	26,175.76	3,000.00	29,175.76
46. Mount Carmel Irrigation Co.	Kane	Diversion dam	500	450	----	14,255.05	8,672.05	22,927.10
47. Orderville Irrigation Co.	do	do	500	258	----	8,286.56	5,648.80	13,935.36
48. Fool Creek Irrigation Co.	Millard	Equipment well	1,200	1,000	300	30,000.00	1,959.00	31,959.00
49. Fool Creek Irrigation Co.	do	Well	1,000	350	----	15,946.32	6,147.94	22,094.26
50. Lynndyl Irrigation Co.	do	do	800	300	----	11,332.87	3,867.13	15,200.00
51. Meadow Irrigation & Canal Co.	do	do	540	(See No. 53)	----	11,500.00	274.00	11,774.00
52. Meadow Irrigation & Canal Co.	do	Pipeline and control structures	2,125	(See No. 53)	----	78,069.05	20,033.79	98,102.84
53. Meadow Irrigation & Canal Co.	do	Well	540	2,500	200	2,330.67	9,165.00	11,495.67
54. Scipio Irrigation Co.	do	Wells (3)	1,800	5,400	----	24,637.47	15,000.00	39,637.47
55. North Fields Irrigation Co.	do	Well and canal lining	1,460	350	----	37,227.55	16,000.00	53,227.55
56. Golden Harvester Irrigation Co.	do	Well	800	650	150	18,000.00	7,714.29	25,714.29
57. Levan Irrigation Co	Juab	do	647	3,200	----	21,450.00	9,192.85	30,642.85
58. DMAD Co.	Millard	Reservoir	11,000	59,000	----	150,000.00	76,000.00	226,000.00
59. Walker Creek Association	do	Well	100	300	----	11,000.00	4,714.29	15,714.29
60. Sinks Irrigation Co.	do	Well and storage pond	900	160	40	12,018.23	4,531.00	16,549.23
61. North McCornick Irrigation Co.	do	Well	1,200	200	----	5,614.86	5,000.00	10,614.86
62. Roswell Irrigation Co.	Morgan	Pipeline	120	900	----	25,000.00	12,000.00	37,000.00
63. Circleville & Loss Creek Irrigation Co.	Piute	Diversion structure	1,000	4,200	----	31,600.45	13,543.05	45,143.50

PLATE 7—Continued

Utah Water and Power Board—Water conservation projects accomplished May 12, 1947, to Nov. 1, 1959—Continued

Project sponsor	Location (county)	Type of project	Project benefits			Project costs		
			Annual water saved or reservoir yield (acre-feet)	Old land (acres)	New land (acres)	Paid by UW&PB	Paid by sponsor	Total cost
64. Bullion Creek Irrigation Co.	Piute	Pipeline and canal	400	650	50	$17,500.00	$1,104.00	$18,604.00
65. Laketown Irrigation Co.	Rich	Canal lining	230	320		10,500.00	4,500.00	15,000.00
66. Woodruff Irrigation Co.	do	Reservoir	2,256	6,000		91,974.00	47,947.00	139,921.00
67. North Dry Creek Irrigation Co.	Salt Lake	Tank and pipeline	200	265		20,500.00	8,785.71	29,285.71
68. Bell Canyon Irrigation Co.	do	Dam enlargement	182	2,018		52,000.00	22,285.71	74,285.71
69. Herriman Irrigation Co.	do	Pipeline	360	1,500		16,884.77	7,236.33	24,121.10
70. Bell Canyon Irrigation Co.	do	do	50	3,400		10,000.00	1,226.96	11,226.96
71. Granite Water Co.	do	do	90	50		7,500.00	40.00	7,540.00
72. Bell Canyon Irrigation Co.	do	Reservoir	488	(See No. 70)		29,873.47	12,802.92	42,676.39
73. Bell Canyon Irrigation Co.	do	Pipeline	200	(See No. 70)		12,518.67	4,433.48	16,952.15
74. Casto Springs Irrigation Co.	do	do	500	250	100	8,806.29	2,805.88	11,612.17
75. Bell Canyon Irrigation Co.	do	do	1,238	2,200	1,000	38,117.85	14,500.00	52,617.85
76. Provo Reservoir Water Users Co.	do	Wells (3)	1,800	5,000		45,333.09	16,500.00	61,833.09
77. South Despain Ditch Co.	do	Dam repair	167	900		987.84	1,207.36	2,195.20
78. Blanding Irrigation Co.	San Juan	Tunnel	1,600	5,240		75,000.00	14,000.00	89,000.00
79. Mount Pleasant-Birch Creek Irrigation, et al.	Sanpete	Well	720	250		11,376.22	3,751.40	15,127.62
80. Fayette Water Co.	do	Water supply system	100	100		22,053.56	15,225.04	37,278.60
81. Gunnison City Canal Co.	do	Canal	700	1,500		20,834.47	27,786.53	48,621.00
82. Gunnison Fayette Canal Co.	do	Diversion dam	100	10,500		5,500.00	2,357.14	7,857.14
83. Rock Dam Irrigation Co.	do	Canal Lining and structures	300	1,500		11,500.00	3,500.00	15,000.00
84. Fountain Green Irrigation Co.	do	Canal lining	200	2,405		8,000.00	7,000.00	15,000.00
85. Moroni Irrigation Co.	do	do	2,000	4,200		42,000.00	42,000.00	84,000.00
86. West View Irrigation Co	Sevier	Diversion dam	100	2,500		5,500.00	2,357.14	7,857.14
87. Central Water Works Co.	do	Water supply system	239	600		26,000.00	3,319.00	29,319.00
88. King's Meadow Ranches, Inc.	do	Pipeline	500	75	125	18,500.00	7,928.57	26,428.57
89. Henefer Pipeline Co.	Summit	Water supply system	50	50		38,236.06	12,030.00	50,266.06
90. Echo Water Co.	do	Well and pipeline	100	20		4,700.00	2,014.29	6,714.29
91. Vernon Irrigation Co.	Tooele	Canal lining	540	700		26,291.71	20,000.00	46,291.71
92. Settlement Canyon Irrigation Co.	do	Pipeline	540	2,000	200	11,405.88	4,888.23	16,294.11
93. Grantsville South Willow Irrigation Co.	do	Pipeline and diversion structure	600	3,000		20,000.00	8,703.00	28,703.00
94. Ouray Park Irrigation Co.	Uintah	Canal	12,000	12,000	3,000	32,000.00	7,327.00	39,327.00
95. Highline Canal Co.	do	Diversion dam	1,500	4,000	1,000	21,344.88	7,023.41	28,368.29
96. Ouray Park Irrigation Co.	do	Reservoirs (2)	1,987	5,000		89,766.40	37,000.00	126,766.40
97. Lehi Irrigation Co.	Utah	Wells (2)	1,500	4,000		31,500.39	8,000.00	39,500.39
98. Pleasant Grove Irrigation Co.	do	Pipeline	700	3,870		2,264.85	2,867.00	5,131.85
99. Alpine Irrigation Co.	do	Pipeline structure and lining	360	1,700		27,000.00	17,500.00	44,500.00
100. Pleasant Grove Irrigation Co.	do	Wells (3)	1,200	(See No. 98)		40,673.39	20,975.00	61,648.39
101. Summit Creek Irrigation Co.	do	Reservoir	1,247	3,000	500	70,000.00	28,671.00	98,671.00
102. Current Creek Irrigation Co.	do	Wells (3)	2,000	3,000		14,651.74	5,794.76	20,446.50
103. West Union Canal Co.	do	Canal lining	3,600	1,350		26,475.60	4,388.25	30,863.85
104. Alta Ditch & Canal Co.	do	Pipeline and siphon	720	305	30	68,536.05	71,244.95	139,781.00
105. Lake Bottom Irrigation Co.	do	Canal lining	1,000	1,500		7,380.75	3,585.30	10,966.05
106. Salem Pond Co.	do	do	200	200		3,000.00	1,285.71	4,285.71
107. North Union Irrigation Co.	do	do	300	3,000		10,000.00	4,285.71	14,285.71
108. Highland Water Co.	do	Water system, pipeline	300	20		140,000.00	60,000.00	200,000.00
109. Summit Creek Irrigation Co.	do	Blanketing reservoir basin	(See No. 101)			6,000.00	2,571.43	8,571.43
110. Charleston Water Conservation District.	Wasatch	Water supply system	100	1,200	20	55,000.00	13,650.00	68,650.00
111. Lake Creek Irrigation Co.	do	Canal (replacement)	900	1,550		6,720.92	1,500.00	8,220.92
112. Jones Reservoir Co.	do	Reservoir enlargement	200	300		9,418.05	10,200.51	19,618.56
113. Daniel Irrigation Co.	do	Canals and siphon	800	1,800		31,000.00	17,198.54	48,198.54
114. Extension Irrigation Co.	do	Canal lining	400	500		15,000.00	6,428.57	21,428.57
115. Bench Lake Irrigation Co.	Washington	Reservoir	250	1,500		12,139.40	27,400.00	39,539.40
116. Bench Lake Irrigation Co.	do	Canal lining	1,500	1,500	500	10,000.00	4,285.71	14,285.71
117. Ash Creek Irrigation Co.	do	Reservoir	6,000	3,640		86,000.00	36,857.14	122,857.14
118. Kolob Reservoir & Storage Association.	do	do	3,000	7,000		162,649.45	108,119.00	270,768.45
119. Baker Reservoir Co.	do	do	1,145	1,200	400	85,607.61	14,392.39	100,000.00
120. Hanksville Irrigation Co.	Wayne	Diversion dam	3,000	660		11,000.00	4,702.00	15,702.00
121. Fremont Irrigation Co.	do	Reservoir	5,232	9,000		246,307.83	32,214.44	278,522.27
122. Weber-Box Elder Pipeline Association.	Weber	Pressure irrigation system	740	750	83	77,000.00	17,045.00	94,045.00
123. South Weber Diversion Canal Co.	do	Diversion dam and canal	1,500	700		10,571.81	4,530.78	15,102.59
124. North Bench Irrigation Co.	do	Pressure Irrigation system	500	200		50,651.45	10,564.39	61,215.84
125. East Willow Springs Irrigation Co.	do	do	400	95		15,634.23	10,000.00	25,634.23
126. Rice Creek Irrigation Co.	do	do	500	900		5,172.28	3,000.00	8,172.28
Total			163,948	314,604	19,435	4,327,984.34	1,752,174.43	6,080,158.77

PLATE 8

Summary of potential water conservation projects in Utah

	Number of projects	Total project cost	Newly irrigated lands	Supplemental lands	New land equivalent	Average allocated cost per acre	Total storage	Average cost per acre-foot of average yield
		Thousands	*Acres*	*Acres*	*Acres*		*Acre-feet*	
Non-Federal to 1980	71	$18,157	34,900	248,990	77,624	$234	179,882	$73
Federal to 1980	12	321,450	22,020	274,000	150,020	176	1,954,160	169
	[1] 4	[2] 395,000					[2] 26,500,000	245
Total to 1980	83	339,607	56,920	522,990	227,644		2,134,042	
Non-Federal 1980 to 2000	25	13,129	0	24,300	5,310	540	28,786	550
Federal 1980 to 2000	4	586,100	145,705	160,302	212,805	2,310	1,093,900	253
Total 1980 to 2000	29	599,229	145,705	184,602	218,115		1,122,686	
Total to 2000	112	938,836	202,625	707,592	445,759		3,256,728	

[1] Major storage units of Colorado River storage project, not included in totals.

[2] 23 percent of total corresponding with Utah's compact allocation, not included in totals.

VERMONT

State of Vermont,
Executive Department,
Montpelier, September 30, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
Senate Office Building, Washington, D.C.

My Dear Senator Kerr: Your invitation to me to make a statement as to the water problems of Vermont, both present and those anticipated to arise between now and 1980, is received with pleasure. Vermont has long been blessed with an abundance of clear, cold water. It is true, however, that our increasing population and changing economy have placed continually increasing demands on this resource and have created many diverse problems.

Our recognition of this water resource problem is evidenced by Vermont's participation in the activities of the New England-New York Interagency Committee. You are undoubtedly aware of this unique undertaking in which the representatives of seven Federal agencies and seven States worked together as a single committee for nearly 5 years to prepare a comprehensive report of the water and related land resources of the study area. This 44-volume report on the water and related land resources pointed out many problems for Vermont and for the entire New England-New York area. It also provided many recommendations for the development, utilization, and conservation of our resources. Undoubtedly, many of the facts contained in the 9-foot shelf space devoted to this report will be utilized by your staff in the analyses of the water problems of our area. I would certainly recommend that your committee give serious consideration to the wealth of material contained in this report.

I believe that our water problems should be analyzed and solved by the regional and interagency approach, recognizing always the sovereignty of the State to bring about the accomplishment of such water resource development as will be considered by the State to be in the best public interest. It is with this in mind that I have named a representative to the Northeastern Resources Committee. This committee, recognized by a charter from the President's Interagency Committee on Water Resources and a memorandum of understanding signed by the Governors of the six New England States, is composed of State and Federal representatives and has as its prime responsibilities to establish means and procedures to promote coordination of the water and related land resources, activities of the States and other Federal agencies, to promote resolution of problems at the regional level, to suggest to the States or the interagency committee on water resources changing all our policy that would promote this coordination or the resolution of problems.

We in New England have long favored the interstate compact approach to the solution of regional problems as is evidenced by the existence of many interstate compacts in this area such as the New England Interstate Pollution Control Compact, the Connecticut River Flood Control Compact, to mention but two. This compact approach in solving interstate problems has been most successful here in New England and I favor approaching our water resource problems in this fashion.

The NENYIAC reports point out that there will be a surplus of water available in most parts of this region, at least to the year 2000. I believe this is certainly true in Vermont. This prediction seems even more secure in light of the progressive pollution-control program administered by our water conservation board. Under its able leadership better than $5 million have been voted by the citizens of our State for needed sewage-treatment plants and intercepting sewers during the past 2 years. This would certainly seem to indicate widespread public acceptance when we recognize that the State's population is less than 400,000.

I note with concern that there is a preponderance of western representation on the Senate Select Committee. Only three members were named for States east of the Mississippi and none of these were from the Northeast. I would respectfully urge that the committee add to its membership a Senator from New England. I feel that this is most significant because of the tremendous difference in the legal concept of water law by appropriation in the West and of riparian rights in the East.

We will appreciate the opportunity of presenting a summary statement for the record at least by the date of your hearing in Boston on December 8.

With best wishes for the success of your studies, I am

Sincerely yours,

Robert T. Stafford, *Governor.*

VIRGINIA

COMMONWEALTH OF VIRGINIA,
COMMITTEE ON WATER RESOURCES
Richmond, Va., September 17, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate,
Washington, D.C.

DEAR SENATOR KERR: In compliance with the request appearing in your letter of June 23, 1959, to Governor Almond, and in keeping with his expressed desire, the following comments pertaining to the situation in Virginia are submitted for consideration by the U.S. Senate Select Committee on National Water Resources.

Rather than attempt to mention points in all recent statements and studies, consideration has been given here to only a few. They are sufficient for our present purposes. Four of them will be referred to by the following numbers and, where appropriate, page numbers will be placed in parentheses:

Reference	*Title*
1	Water Resources and Power—A Report to the Congress by the Commission on Organization of the Executive Branch of the Government. June 1955.
2	Natural Resources and Conservation—Submitted to the Commission on Intergovernmental Relations by the Study Committee on Natural Resources and Conservation. June 1955.
3	Water Resources Policy—A Report by the Presidential Advisory Committee on Water Resources Policy. December 22, 1955.
4	1958–59 Policy Declarations on Natural Resources and Atomic Energy—Chamber of Commerce of the United States.

In general the water problems in Virginia which either exist now or are expected to arise by 1980 are those incident to population increases, industrial expansion, pollution abatement, navigation requirements, reduction of flood damage, changing agricultural procedures, greater interest in fish and wildlife, the growing need for recreational facilities, and the activities of various groups and agencies.

Municipal and industrial supplies.—It appears probable that our population will increase from an estimated total of 3,970,000 this year to 5,700,000 by 1980. Industrialization will undoubtedly keep pace with and be responsible for a large part of the increase. The need for additional municipal and industrial water supplies will grow concurrently. However, we are confident that the needs will be met as there is an adequate natural yearly supply. We concur in the view expressed in 1(29), 3(31), and 4(29) that provision of such supplies is not a Federal responsibility. This is true even though there are and will continue to be cases where local governing bodies feel that they lack the financial ability to take advantage of authorizations appearing in the Water Supply Act of 1958 and the Watershed Protection and Flood Prevention Act. They, as well as industries which are unwilling or unable to finance the necessary developments, will find that, without development of additional supplies, there is a limit to their growth and that restrictions on water use are necessary from time to time. Conditions are no longer such that adequate supplies of water are always available for little or no cost.

One specific case, in which the Federal Government has both an interest and a responsibility, should be mentioned. In large measure, activities of the Federal Government are responsible for the rapid and continuing increase in the population of that section of Virginia embraced in the Washington metropolitan area. The need for augmenting the present supplies of water may arise soon. The logical source of supply is the Potomac River. Presently, the matter is part of an overall study of the Potomac River Basin called for in a resolution adopted on January 26, 1956, by the Committee on Public Works of the U.S. Senate. This portion of the study should be completed, by making an interim report if necessary, and acted upon promptly. The cost of providing the additional water should be borne by the users.

Pollution abatement.—Most water pollution problems result from municipal and industrial use of water. Since 1946 Virginia has operated under the provisions of an effective State antipollution law. In addition we participate in appropriate interstate compacts. Much progress has been made. With the benefit of Federal research (particularly in the radioactive field), investigation, and assistance under the Water Pollution Control Act, we will continue to concur in the belief that this control is primarily a State responsibility, as expressed in 1(29), 2(13–14), 3(3), and 4(31), and act accordingly.

Navigation.—Adequate navigation facilities are essential to the economy of Virginia and the Atlantic coast. The Federal Government carries out the responsibilities of the Commerce Clause of the Constitution and, under congressional authorizations, studies the needs and justifications for navigation improvements. As long as the drafts of oceangoing ships continue to increase there will be a demand for greater channel dimensions if the natural harbors and ports of Virginia are to be used efficiently. Although on a less spectacular scale, the improvement of channels to and turning basins in our numerous tidal estuaries are important to our economy. Frequently such improvements are needed to correct damage due to storms or other natural causes. At times minor improvements are made by the fishermen but without Federal projects there would be an unacceptable curtailment in the national seafood industry. In general, the situation is satisfactory but there are individual cases of justifiable projects where the recommended "local cooperation requirements," particularly the cash contribution, are beyond the financial ability of the area.

Reduction of flood damage.—The reduction of flood and storm damages is an ever-present problem. Like other States along the Atlantic Seaboard, Virginia suffers from salt water damage during adverse conditions of tide and wind. Investigations to date indicate that only in rare cases will it be feasible to justify the costly and extensive construction needed to protect against hurricane damage along out coast and that, in many instances, no improvement is physically possible. Floods and storms also cause damage to our shores and beaches. Presently there are two authorized beach-erosion projects in Virginia and experiments are continuing in an effort to reduce the erosion of stream banks.

Fortunately it is possible to reduce damage caused by excessive fresh water runoff. These possibilities range from measures available to individuals to those requiring large structures on the main rivers. All appropriate measures, including flood plain zoning, are important to the attainment of the overall goal. There is compelling need for coordination and correlation. There has been much open, harmful, and unwarranted discussion in the "big dam—little dam" controversy. Both types of dams, as well as soil-conservation practices, are valuable and each has its place in the solution of the problems involved. Some needed undertakings may have been delayed by the changes in Federal policies on the financing of flood control projects but the work of the U.S. Corps of Engineers in flood control and the work of the U.S. Department of Agriculture in waterflow retardation and soil erosion prevention are beneficial to our Commonwealth. In general we concur in the expressions on "Flood and Rising Water Control" in 4 (29, 30).

Agriculture.—During the next 20 years there will be need for continuing the most beneficial methods of solving the routine problems of agriculture incident to too much or too little water. Advances will be made in practices of drainage and irrigation and farmers will be encouraged to use them. While there is some question as to the probability, there is certainly the possibility that, by 1980, the population will begin to press upon the food supply. When that occurs, Virginia will join other States in intensifying its production and growing a larger acreage of "high per acre value" crops. Competition will be greater and price levels will probably be higher. Supplemental irrigation would be more necessary under those conditions than at present and additional State and Federal legislation may be needed. Through the passage of permissive legislation in 1956 the General Assembly of Virginia endeavored to encourage the capture of flood waters for uses such as irrigation. The use of supplemental irrigation is increasing and the recent dry summers are forcing many farmers to study the possible advantages of its use. It is important that they realize that the success of irrigation depends on more things than a supply of water.

Fish and wildlife.—All indications lead to the conclusions that additional development of our water resources will be needed for fish and wildlife purposes. Virginia has a very active program in this field and several impoundments have been provided for public fresh water fishing. This is proceeding along with similar programs for wildlife conservation. The present Federal-State relationship is satisfactory. Salt water sport fishing is being encouraged.

Recreation.—Seldom, if ever, is there a natural body or an impoundment of water which fails to contribute to the facilities available for recreation. Many artificial ponds and lakes are provided for that specific purpose. There is no question but that there will be a continuance of the present practice of using water resources developments to promote these benefits.

Activities of groups and agencies.—It may be that your request did not contemplate remarks such as those which follow but they are being included because the matters to which reference is made have presented and will continue to present real problems concerning water resources. Basically they are traceable to a malady to which most men are susceptible—that of forgetting the "grass roots." In its worst phase this disease has been referred to as the "Jehovah complex." That is a general statement which is applicable in so many local, State, and higher echelons of government that it should not be applied solely to any single one.

For many years effort has been made to recognize the "grass roots" in the conservation of natural resources by encouraging the formation of river basin associations. Two are functioning and a third one is being organized. These are composed of interested individuals, residing in the watershed, who, with us, believe that those who should have a great influence in guiding the development in a given river basin are the people who live in it. Assistance from State agencies is available to these associations but no State employee serves, as such, in any official capacity in the organization. It appears logical that the same principles are applicable to interstate river basin associations so that the representatives of the affected States will have a definite preponderance of voting strength. You can understand why we are concerned about the following statement in 3 (17) as part of a discussion of membership on river basin water resources committees:

> The total number of either Federal or State representatives is regarded as immaterial, since the conflicts should be resolved by cooperation and not by voting strength.

State representatives are interested in good conservation—wise use and intelligent development—and, if they cannot be convinced, there is a strong probability that the proposal doesn't deserve support. No Federal project should be approved by the Congress without the concurrence of the affected States.

Then, too, we are perturbed by the many water resources conflicts between the Western States and certain Federal agencies. This question is discussed in 2(8) and 4(18). This subject is far more active in the Western States than in the Eastern States but the trend toward a disregard of State water laws is disturbing. Admittedly there are times when governmental employees, who are familiar with the development needs, feel impatient over the apparent inertia of those who might be acting. But this does not make logical any idea similar to that expressed in 2(9) to the effect that—

> The failure of these States to promptly assume their responsibilities creates a vacuum into which the Federal Government tends to rush, thus unbalancing intergovernmental relationships.

It is to be hoped that such sentiment is not representative of the Federal attitude. There should be no Federal encroachment on State water laws or uses 1(36, 37).

It is also our hope that the "Threat of socialization of water resources," mentioned in 4(20), will be recognized by the Congress in its actions to preserve our free enterprise system. Authorization for a private power company to build a hydroelectric project on the same river (Roanoke) with two Federal projects is a comforting indication. Financial encouragement in the form of tax relief for such undertakings would be beneficial.

There is another condition about which we worry since it is detrimental to the conservation of our water resources. It pertains to what is believed to be a difference between congressional intent and administrative determination. It concerns the cooperative investigatory programs. Ever since our general assembly directed that, after June 30, 1957, no State funds be paid to any Federal agency as part of our participation in cooperative water investigatory programs, effort has been made to reestablish cooperation without a transfer of State funds to the U.S. Geological Survey. So far as we know there is no congressional directive as to the means which must be used by a State to satisfy its portion of a cooperative investigatory program. If that be true, the apparent unwillingness of the director to renew the cooperation, without a cash contribution from Virginia, is based primarily on an administrative decision. While Virginia funds are being used for water resources investigations, no matching Federal funds are being spent for a cooperative program. This has had an adverse effect. Such program as is being undertaken by the USGS in Virginia is restricted to the interests of agencies other than State water resources agencies.

One other correctible condition involves the variations in methods and procedures followed by different Federal agencies. This matter is discussed at some length in 3(2,13–16). Under present conditions it is possible that there may be some playing of "one Federal agency against another to secure the greatest benefits" as stated in 1(16).

General.—As stated by the Engineers Joint Council in 1951.

> To date no one has had the information or the wisdom to determine how the future course of our water development could be charted indefinitely into the future. There is a practical limit to which even good planning can be carried without becoming a detriment rather than an aid in development.

We concur also in a similar statement concerning large river basins appearing in 3(3, 4).

We agree that water rights are property rights—3(xii)—and that "A uniform national blueprint for water resources development is neither practicable nor desirable"—3(13). Nor is a uniform State blueprint practicable or desirable.

With a firm conviction as to the necessity for an understanding of the problems and proposed solutions by the residents of a watershed or river basin, we would encourage action by all levels of government to acquaint them with the facts and enlist their interest and support in reaching sound decisions. The river basin organization, whether intrastate or interstate, offers the greatest promise for the best results despite the fact that it may be cumbersome and progress may be slow.

Should your committee publish a report, it will be appreciated if 25 copies are sent to us.

With kind regards, I am

Sincerely,

W. Martin Johnson, *Chairman.*

WASHINGTON

State of Washington,
Executive Department,
Olympia, October 5, 1959.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: Pursuant to your request of June 23, the statement of the State of Washington is herewith submitted concerning the problems, surveys, and plans confronting us in the field of water resources now, and anticipated by 1980.

Realizing the importance of the study undertaken by your committee, we wish to thank you for giving us the opportunity to express our views and to advise that we stand ready to further assist you in any way possible.

We will be most pleased to send additional copies of this report if needed.

Sincerely,

Albert D. Rosellini, *Governor.*

Summary Report of State of Washington to U.S. Senate Select Committee on National Water Resources

INTRODUCTION

This report has been specifically organized to follow as nearly as practical, the procedural outline submitted to us by your committee and represents the collective efforts of all State departments having an interest or specific duties to perform in the field of water resources. The department of conservation and its division of water resources has been given the primary responsibility for preparation of this report but the other departments listed below, have contributed information and data on specific items of your outline which are associated with their responsibilities and specific interests: Departments of game, fisheries, health, agriculture, commerce, and economic development, pollution control commission and weather modification board.

Such that your committee can more readily envision the problems facing each of these agencies, complete statements of those participating have been incorporated as an addendum to the summary report.

GENERAL STATEMENT ON WATER SUPPLY

Climate and runoff problems.—The problems of water management in the State of Washington are probably more complex and more numerous than those of any other State in the Union. Such a statement is based on our many divergent uses, extreme range in climatic conditions (see addendum No. 1), topographic elevations and our geographic location involving other nations and other States. Temperatures vary from a minus 40° on our 10,000 to 14,000 foot glaciated peaks to 120° F. in the arid portions of eastern Washington near the 400-foot elevation level. Our range in precipitation is from 5 inches in the arid portions of central Washington to over 200 inches in the rain-forests of the Olympic Peninsula. Our watersheds vary in size from less than 1 square mile to the entire three-fifths of the total area of the State of Washington which comprises our share of the great Columbia River Basin.

Geographically and climatologically speaking, the State is divided in two parts by the Cascade range of mountains. Over 100 million acre-feet of water falls in the form of precipitation on the westerly two-fifths of the State, while only 41 million acre-feet falls on the easterly three-fifths of the State. Approximately one-half of the precipitation is discharged to the Pacific Ocean by our Puget Sound and coastal streams. Less than 20 percent of this precipitation falls during the growing season. The heavy winter flows of these streams create flood damage problems (see addendum No. 4), and the very low flows of the summer months create problems of pollution, insufficient water for preservation of fish life, and the heavy demands made upon the available supply by the municipal, industrial, and agricultural uses. As an example of the extremes that can be encountered in the coastal river basins, the Chehalis River, at Grand Mound, varies from a maximum instantaneous discharge of 48,400 cubic feet per second in December, to a minimum of 90 cubic feet per second in August, with an average annual discharge of 2,675 cubic feet per second. In the lower elevation of the Puget Sound agricultural areas, supplemental irrigation in the amounts of 2 acre-feet per acre, are sometimes necessary for full crop production. This places a further demand on the rapidly disappearing summertime water supplies of the western portion of our State. The one benefit derived from heavy winter discharge in the coastal streams is in the development of high-head hydroelectric power which complements the low discharges encountered in the Columbia River Basin during the late fall and winter months. The many and varied problems of all the multiple purpose aspects of the full development of the Columbia River Basin in the conflicts of the use of this great supply should be well known to your committee. However, such that you may be informed of the needs of this area for basic data, we would like to refer your committee to the addendum statements of this department on climatology (addendum No. 1), groundwater geology (addendum No. 2), as well as to the Columbia Basin Inter-Agency Committee, hydrology subcommittee summary, which is also submitted as addendum No. 5 to this report. It may be added that watersheds originating in the State of Washington contribute approximately one-third the total annual runoff of the Columbia River Basin.

Required surveys and studies.—The percentage of our annual runoff which can be effectively conserved, is believed to be an unknown quantity at the present time. Realizing that our rapid population and industrial growth is to place an ever-increasing burden upon our existing supply, we are beginning an inventory of this supply and its present use. A survey of the projected demand upon this supply will also be conducted and a plan of ultimate development of our water source must follow in the very near future. In so doing, we not only expect to coordinate the efforts of our own State and local agencies but it is our desire that we can also coordinate and consolidate our studies and plans with all Federal agencies. Further realizing that our extremes in climatological conditions and maldistribution of the water supply is unusual, we feel we must request basic data collection and information which is more adaptable to these unusual conditions. We expect to enlarge upon our program of collecting these data in the areas in which it is needed and likewise expect the cooperating Federal agencies responsible for such data to accelerate their programs and adjust their networks for more effective results.

We are further initiating, for the first time, a water quality network of sampling stations including some 66 on the streams of our State and over 100 observation wells. The quality of our waters and the effective retention of that quality, is now considered to be one of the most important factors in planning the ultimate development of the remaining supply. The data thus obtained and the need for accelerating such a program of quality investigation, should be of grave concern to all agencies, both State and Federal, that are involved in water resource development. Every effort should be made to standardize procedures of sampling, collection, and analysis, such that reliable data is made available to all agencies.

PROJECTED DEMANDS UPON WATER SUPPLY AND PROBLEMS OF THE FUTURE

Population projections and municipal use.—Included as addendum No. 11 to this report, is a bulletin of the Department of Commerce and economic development entitled "Economic Horizons," which gives population projections for the State of Washington through 1975. Extending this in a straight line projection to 1980 would indicate that our population would increase from present day estimate of 2,883,000 to 4,430,000, or an increase of approximately 57 percent. Increased municipal supply use should parallel the population growth with an upward trend in per capita per day consumption, raising the percentage increase above that of the projected population increases.

Agricultural needs.—Water requirements for agriculture fluctuate with economic and precipitation cycles. However, the overall demand should increase at a rate closely paralleling our population percentages. Improved irrigation practices resulting in more efficient use of water, could slow this rate of increase to some extent. We do not anticipate that the limit of irrigated acreage will be reached by 1980 as may be further corroborated by the Columbia Basin Depletion Studies conducted by the Water Management Subcommittee of the Columbia Basin Inter-Agency Committee.

It is estimated that 1,200,000 acres of land are irrigated at present and based on the indicated trends, this should increase to 1,500,000 by 1980 and require another million acre-feet of water from remaining supplies. Total irrigable acreage in the State is expected to exceed 3 million acres. Actual development of presently authorized Federal reclamation projects could increase the 1980 figures.

Industrial use.—Principal industrial demands on water in the State total 1.2 billion gallons daily. (See pollution control commission report—addendum No. 7.) Using historical growth data as well as 3 to 3.5 percent anticipated annual growth by the timber products industries, the demand by 1980 will have doubled and thus outstrip population projections. If these prove correct, this may also accelerate the rate of population increase. The timber products industry, led by our pulp and paper plants, represents 70 percent of the total industrial demand. However, the petrochemical and metals group is expected to increase faster and represent more than the present 20 percent of the total.

Power use

Closely associated with industry is our great hydroelectric power resource often estimated at 40 percent of the potential of the entire United States. Records of the power suppliers show that our annual average domestic consumption rate is about 8,500 kilowatt-hour per customer or almost three times the national average (see addendum No. 3) and that all indications point to an even higher rate of consumption in the future. With a conservative 6-percent-per-year average increase predicted, our total consumption in the State will increase from 23.5 billion kilowatt hours to 106 billion by 1985. One of the biggest problems to be solved is that of fish passage such that remaining sites can be fully developed. Even with full development of the economical hydro sites, thermal generation in the amount of 8 megawatts will be necessary to provide peaking capability and reserve for the year 1985.

Flood control problems (see addendum No. 4).—Annual damages from minor floods on many of our Puget Sound and coastal drainages, run into millions of dollars—yet many investigations both Federal and State have failed to reveal favorable benefit-cost ratios when considering a project on any one stream. Since it is apparent we can no longer countenance incomplete or single purpose development on any of our watersheds, these damages must continue until complete multipurpose upstream storage becomes feasible. Consequently, the State flood control program endeavors to maintain existing structures and carry on improvement works in the most critical areas through cooperative financing with local groups to the extent of $1 million annually. Eventual stabilization of river discharges through increased use and storage should largely alleviate this aggravating problem.

Fisheries, game, and recreation problems (addendums 8 and 9).—The very existence of our great commercial and sport fishing industry depends entirely upon an adequate supply of water in our streams and lakes to support the runs of migratory and game fish. Increasing demands on the remaining supply for consumptive use diversions, high dams for the production of power and water for waste disposal, present a constant threat to the perpetuation of this great and increasingly important industry. Therefore, the planning of any water development project must give proper consideration to the needs of fish, wildlife, and general recreation purposes. Boating, fishing, and hunting predominate in the recreation interests of the rapidly growing Northwest area. Therefore, recreation requirements become closely associated with those of the fishing industry. Yet even these uses come into conflict between fishermen, swimmers, and skin divers on one side and the pleasure boaters, speedboaters and water skiers on the other. There is a definite need for standardized safety regulations in the operation of all types of boats, adequate marking of swimming and skin-diving areas in both salt and fresh waters.

Public water supply and waste disposal problems.—Increased per capita consumption, rapid growth of small communities, building of roads, increased recreational activity, and logging of our watersheds, have multiplied the problems of keeping our water supplies in a safe clean condition. (See addendums No. 6 and 7.) Many communities are faced with reaching out for more adequate supplies and have the additional burden of enlarging overcrowded waste-disposal systems or constructing new ones to comply with health and pollution statutes. Unless our watersheds are properly managed and the water constantly monitored for allowable degrees of pollution, these smaller municipalities will be faced with a still further financial burden of treatment and filtering facilities.

MEANS OF MEETING FUTURE DEMANDS

To meet future demands we must first know everything possible about the supply and how it can be augmented. This means accelerated research into all the fields of basic data collection and compilation and should include glacier studies, snow surveys, watershed management, locations of precipitation and stream gaging stations, new techniques in remote control and automatic recording, compilation of data by machine methods, quality control, and pollution abatement. To augment the supply, research must also cover induced precipitation, new techniques in reservoir location and construction, artificial ground water storage and ground water recharge. Local financial participation is to be expected on phases peculiar to no other area.

Investigations and planning for development should no longer be considered on a project basis but must be directed toward complete and ultimate development for all purposes on a watershed by watershed basis. All such investigations and plans must be coordinated with local, State, Federal and, when necessary, international agencies.

Project authorizations should receive favorable consideration at such time as all investigations and planning have been completed and only if it is in accord with the approved plan for complete and ultimate development of the entire watershed.

WHO SHOULD DO WHAT

Research, collection of basic data, investigation and planning are of primary concern to every individual and should be supported through general taxation with special information for local areas being financed through recognized formulas of cooperative support. The Federal agencies have accepted the basic responsibility in the fields of research and data collection and should continue to do so. However, methods, techniques, and procedures should be adjusted to suit local and regional conditions of topography, climate, and uses of water.

Investigation and planning should be done on a cooperative basis with local agencies assuming the responsibility for specific interests with Federal Government financing the phases covering national interest.

Integration and coordination of plans and investigations must be accomplished to avoid duplication of effect and expenditure.

Large construction projects generally involve several phases of national interest and, therefore, become the responsibility of one of the Federal operating agencies when it comes to design, allocating of costs, and repayment policies.

Review of cost allocation formulas will be required in that most favorable and economical projects have already been constructed. Reclamation and municipal water supply features must be commensurate with the water users ability to repay.

Regulation and control of the use of water is a primary State responsibility and its power of administration must be recognized by all other agencies such that orderly development and use can be perpetuated.

ADDENDUM No. 1

CLIMATOLOGICAL PROBLEMS OF THE STATE OF WASHINGTON—REPORT OF WEATHER MODIFICATION BOARD, DEPARTMENT OF CONSERVATION

(Submitted by Department of Conservation, Weather Modification Board)

The Cascade Mountain Range, paralleling the Pacific Ocean shoreline, forms a barrier which tapers from 8,000 feet along the Canadian border to 4,000 feet near the Columbia River and thus partitions the State into two distinct climatological regions comprising 40 and 60 percent of the total area. The climate of the smaller western area is dominated almost entirely by maritime air mass intrusions that are controlled by the north Pacific anticyclone. During the summer months, a northward extension of this mountain of air effectively blocks off migrant cyclonic storms such that during the months of July and August precipitation equals less than one-quarter of the average crop requirement. The severity of this shortlived drought is intensified by the abruptness of its beginning. During the normal spring, frequent recessions of the Pacific ridge allow moisture laden storm systems to supply abundant rainfall to initiate a luxuriant plant growth. Then, rather suddenly, the buildup of the ridge excludes virtually all storms, leaving the dense, shallow rooted vegetation in an environment entirely adverse to that enjoyed during early development. Less than 20 percent of the average annual rainfall occurs during the growing season on the west coast. This imbalance in the temporal precipitation distribution becomes critical during July and August which average less than 1 inch per month over the agricultural lowlands of Puget Sound. Since this insidious phenomena, a transient but acute drought masked by seemingly ample annual precipitation, is peculiar only to the Pacific Northwest, it has received little attention as a climatic factor indicative of the need for supplemental irrigation.

During the months of September and October, the protective dome of air that has occupied the northeastern-Pacific begins a gradual deterioration. This allows moisture laden cyclonic storms generated in the vicinity of the Aleutian Islands to invade the Pacific Northwest with ever-increasing frequency, reaching a maximum during the month of December. Forty percent of the annual precipitation is deposited during the last one-third of the year. With the storm frequency decreasing, the 4 months January through April contribute a comparable amount, bringing the total to slightly over 80 percent of the annual precipitation occurring in the "water surplus" season, i.e., characterized by an excess of precipitation over evapotranspiration. On the average, most of this water falling as rain, on the elevations below 3,000 feet, is rapidly dissipated in surface runoff. A hydrograph of a typical rainfed western Washington stream emphasizes this point.

Runoff from precipitation falling as snow above this 3,000-foot contour is retarded in direct proportion to elevation, shaded exposure, and accumulated depth. It is this snowpack which lessens the severity of wintertime floodflows and makes possible a more efficient utilization of the resultant water as it is automatically released in accordance with the increasing water requirements during the summer season. Because of our northerly latitude and maritime climate, the average ablation of this snowpack is incomplete. The State of Washington is distinctly unique in having an area under permanent ice cover that is nine times the combined areas of those found in the 47 other contiguous States. Likewise, termini of these glaciers are found at the lowest elevations. The benefits derived from the timely occurrence of glacial runoff will become increasingly more important as demand for water increases.

Climate in the eastern three-fifths of the State is controlled to considerable extent by the Cascade Range. Maritime air masses undergo considerable modification while flowing eastward over this barrier. Likewise, the protection of the Rocky Mountains to the east prevents the predominance of typical continental air masses. The annual march of precipitation in this region is similar to the west coast except that the quantitative differences between months and extremes is considerably less. Notable, also, is a marked change which occurs during May and especially June, when monthly precipitation amounts approach or even exceed the December maximum. The causes of this phenomena are believed to be not thoroughly understood. Annual evapo-transpiration exceeds precipitation in most all lowland areas, such that irrigation is practiced whenever feasible.

Perennial streamflow on the east side is confined to water courses with headwaters in higher elevations which are sustained by the accumulation of winter precipitation in the form of snowpack. Except for an occasional early "spring thaw," hydrographs of these streams exhibit early summer peak flows as opposed to midwinter maximums experienced along the west coast. Although these peak flows occur nearer to the season of maximum agricultural requirements, supplies become inadequate in mid-July when all but the most favorably located snowfields have melted. It is at this time the ablation from glaciers on the east slopes of the Cascades contribute a significant proportion to the water supply of eastern Washington.

Considerable effort is being devoted by State and Federal agencies to develop and conserve the country's water resources. The emphasis is, of course, on the immediate and the universal problems.

Our State with an annual average areal precipitation of 40 inches, and, more emphatically, the western Washington portion, receiving a similarly distributed 70 inches, incurs water supply conditions which are generally not associated with other regions. Because of our unique geographical and climatological position, we are presented with resources and confronted with problems of their development which are not of universal interest. Therefore, the impetus to examine these peculiarities must be initiated and supported by our State.

From the hydrological viewpoint, one of the most glaring deficiencies occurs in the distribution of climatological data collection stations. From a total of about 250 units sampling precipitation and/or temperature only, 11 are located in the Cascade Mountains above the 3,000-foot level. Of this number only three are above 4,000 feet.

According to the policy followed by the U.S. Department of Commerce, Weather Bureau, the majority of the stations in this State and in the Nation are manned by cooperative observers who serve with little or no pay. This restricts data collection to the accessible and populated areas. Therefore, in order to secure the data we require and to adequately sample our remote but substantial water-producing areas, it is necessary that the State support the program.

Individual glacial areas of the State have received some attention mainly for their facility to integrate climate and thereby give some clue of long-term trends. Additional information is required to determine the extent to which these icefields can be utilized for production of additional water.

One of our most promising sources of additional water supply is expected to come from "cloud seeding." The moisture-laden cyclonic storms that cross our State in winter with a frequency exceeded only by Alaska offer ideal meteorological conditions for increasing snowpack. Here again, this distinction requires that the State take the initiative and actively participate in the national weather modification research program already in its second year of study.

ADDENDUM No. 2

STATEMENT OF GROUND-WATER CONDITIONS AND PROBLEMS

(Submitted by Division of Water Resources, Department of Conservation)

Underground reservoirs in the State of Washington have storage water in amounts that far exceed the total capacity of all the State's surface reservoirs. This includes Grand Coulee and other large reservoirs on the Columbia River system. Water in underground storage enjoys certain advantages not available to surface reservoirs. For the most part, ground water in storage is not susceptible to the large evaporation losses experienced by surface water reservoirs. Temperatures and chemical qualities of ground waters are more constant and the water less susceptible to contamination. Underground storage does not necessitate the construction of costly reservoirs, transportation canals, and filtering plants. As readily available surface water supplies are depleted, more and more we will turn to this great underground reserve of water for the State's future development.

Since geologic conditions of an area control the occurrence and behavior of underground waters, a thorough understanding of the geology is a necessary prerequisite to the administration of an orderly development of this vast and important resource. In many areas of the State extensive ground-water development has outstripped the rate of geologic investigations and, as a result, in some areas the quality and quantity of ground water has been impaired.

The State of Washington generally can be divided into two major geologic areas with reference to the production of ground water. East of the Cascade Mountains the Columbia River basalt flows cover most of the southern three-fourths of the area. These basaltic lavas are the chief source of ground water east of the Cascades and are penetrated by thousands of wells which produce water in amounts ranging from a few gallons per minute for domestic supplies to several thousand gallons per minute from some of the more important wells furnishing water for irrigation, municipal, and industrial supplies.

Of lesser importance, but still an important source of ground water in some areas of eastern Washington, are the sands and gravels of glacial and postglacial origin. In some areas these materials produce large amounts of water from relatively shallow wells. The city of Spokane obtains its entire municipal water supply from these materials. Individual city of Spokane wells have capacities of as much as 35,000 gallons per minute.

A large amount of factual data has been compiled by State and Federal agencies on the water-bearing characteristics of the basalt and postbasalt formations; however, much additional information is needed to serve as a guide to an orderly development of these waters. In the past our effort has been directed toward collection of factual data and geohydrologic mapping. We must now place a greater emphasis on a quantitative and qualitative analysis of existing supplies and evaluate how these supplies can be augmented by planned artificial recharge or by recharge incidental to irrigation projects.

The glacial and postglacial sand and gravel formations of western Washington are the chief sources of ground water west of the Cascade Mountains. Wells penetrating these formations produce from a few gallons per minute to nearly 10,000 gallons per minute. These materials are the source from which many irrigation, domestic, and municipal water supplies are obtained.

Most of the more heavily populated areas of western Washington have had at least a preliminary or reconnaissance-type geologic study completed; however, because of the complex nature of the glacial deposits, much additional work need be done. In addition to quantitative and qualitative problems that must be met, western Washington faces a serious potential problem of salt water intrusion. Although, to date, this is not a major problem, we know of wells which have been abandoned or suffered deterioration in water quality as a result of salt water intrusion. If the problem is not given adequate attention, it could result in serious damage to, or eventually destroy, some of our underground reservoirs.

Although the State of Washington in cooperation with the U.S. Geological Survey maintains a cooperative ground-water program amounting to about $65,000 per biennium it is felt that the program is inadequate and our rate of geohydrologic mapping, as well as quantitative and qualitative studies, must be increased if we are to intelligently administer the development, appropriation, and use of the State's ground-water reserve.

ADDENDUM No. 3

PROJECTED POWER DEMANDS OF THE STATE OF WASHINGTON

(Submitted by Division of Power Resources, Department of Conservation)

Historic records of the utilities serving the people of the State of Washington reveal that the average annual domestic consumption has climbed steadily from a rate of some 2,800 kilowatt-hours per customer in 1945 to about 8,500 kilowatt-hours per customer in 1957, while the national average of 1,300 kilowatt-hours per customer in 1945 has increased to 3,265 kilowatt-hours per customer in 1957.

These figures are impressive, but they do not constitute a limit insofar as electrical use is concerned in this State.

Twenty-five northwest utilities already report their annual average domestic requirements exceed 10,000 kilowatt-hours per customer. Clark County, Wash., Public Utility District, advises that among their 28,500 residential customers 78 are using 48,000 kilowatt-hours per year; 204 use over 40,000 kilowatt-hours; and 2,036 are using over 25,000 kilowatt-hours annually.

The State is now nearly completely electrified and further growth in customers will be dependent almost entirely on the population increase. However, the increase in use per customer is expected to continue at a more active pace as witnessed by the Clark County figures given above. Certain heavy-use appliances with low market saturation, such as air conditioners and electric heat, are almost certain to contribute to this trend. We expect the annual consumption to double in the next 10 years.

Increases in commercial energy requirements, likewise, will tend to parallel population growth though at a slightly higher rate. Competition, which in turn will stimulate modernization and mechanization, will contribute to increased use of energy by commercial customers. An annual increase in commercial energy requirements of 7½ percent is forecast over the next 10-year period.

As population grows in the State, new markets will develop and an economy which has been largely agricultural, timber, and mining will be augmented by petrochemical, electrochemical and other heavy industry. Over $½ billion has already been invested in refineries in the Puget Sound region since 1955, and eastern Washington is now witnessing new agricultural-chemical plants under construction. The combination of untapped mineral reserves and potential hydroelectric energy at low cost are almost certain to bring about new industry and expansion of existing plants for annual load increases of not less than 6 percent, and some economists believe a more nearly correct figure is in the neighborhood of 7 percent.

Combining these expected increases an annual average of 6 percent increase has been used, which we feel should be the minimum goal for continuation of hydro development if we are to meet the energy requirements of the State. A total of 23,545,300,000 kilowatt-hours was consumed in this State in 1958. On the basis of the 6 percent annual increase (compounded) load requirements by 1985 should reach 106 billion kilowatt-hours.

Because of pooling arrangements between the generating utilities in this State with those in neighboring States of Idaho, Montana, Wyoming, Oregon, and Utah, and to lesser extent with British Columbia, the distribution of energy produced in this State is not limited to the State's political boundaries. Instead, it is interchanged when and where needed throughout the entire Pacific Northwest through the northwest power pool. At the present time installed capacity in the State is slightly less than 6 million kilowatts (accrediting one-half of the output of existing interstate dams to Washington). If each and every machine included above could be operated at a 50 percent capacity-factor it would just meet the present loads of the State, even with 13 million acre-feet of storage in the system.

It then becomes obvious that we must continue the development of the remaining hydro resources and, where possible, provide additional storage if loads are to be met 25 years hence. To accomplish this we feel the following recommendations are of prime necessity:

1. To solve fish passage problems which are inherent to the construction and operation of dams on northwest rivers.
2. To provide adequate advance planning for remaining sites in respect to comprehensive development so that delays can be avoided once authorization is received.
3. Implementing storage facilities where possible to increase capacity factors to optimum.

Even with these factors satisfactorily provided, we foresee the need for thermal electric plants to supplement seasonal or cyclic deficiencies, and to provide peaking capability and reserve. On a regionwide basis the total installed thermal need is estimated to be very near 8 megawatts by 1985. Because of the availability of coal resources in the State of Washington, we firmly believe that the State must be prepared to carry its full share in developing this source of power. To adequately plan for the utilization of such fuels we need a full inventory of this resource, which will require time and funds, but which we have already begun on a preliminary scale. It is our further recommendation that such a study be continued and expanded as rapidly as possible for the need for such information is past due and any further delay will only add to the possibility of power shortages in the area, this would prolong the period of "colonial" development and a raw resource economy, rather than a balance of industrial development.

ADDENDUM No. 4

FLOOD CONTROL PROBLEM FORECAST FOR 1980

(Submitted by Division of Flood Control, Department of Conservation)

The problems of, and plans for, flood control may not be readily considered on the supply-demand relationship alone, as may be water use and disposal. Providing for flood-control protection, from minimum to maximum degree, requires consideration of the human psychology involved, the degree of protection that psychology will support, the existence of a favorable benefit-cost ratio and the financial ability of the beneficiary(ies).

In most instances, at least as applied to conditions in this State, providing for flood-control protection of a level greater than a 5- to 10-year frequency is almost wholly contingent upon the comprehensive development of the full water resources of which flood control is an integral part. Therefore, until our economy and growth upon the flood plains requires the comprehensive development of the full water resources, supported by that complete family of beneficiaries, our flood-control fight is one of "maintain and hold" rather than "plan and build." In the meantime, we continue to suffer the wasteful and consequential flood losses.

State participation in the cost of flood-control maintenance work has been actively pursued since 1943. Since about 1950 local authorities (counties, cities, diking, drainage, flood-control and soil-conservation districts—

municipal corporations under State law) together with the State, have expended approximately $1 million annually in pursuit of a "defensive maintenance" flood-control program. This includes doing work where most needed in maintaining existing dikes, banks, and channels on an urgent or emergent basis. When a nondamaging flood season occurs this basic program is extended to include improvement and betterment of some floodworks and channels. Our program at all times has been geared to deploying limited available funds where they will do the most good, rather than having a definite program of improvement and appropriating funds to carry it out.

We, with our people, fully realize that the most positive means of flood control is upstream storage. The relative small land area and people receiving specific flood control benefits therefrom cannot support that cost alone nor is that specific, single purpose in the best interest of a comprehensive development of our full water resources. Unfortunately, full development and the immediate needs for flood control are widely separated timewise. Either flood control must wait or the scheme of evaluating "economic justification" must be broadened so as to include other benefits and other or all water resource development within that watershed in advance of a normal or natural development schedule of those individual water resources.

It is apparent that the accomplishment of required flood control in this State rests with the solution to our future supply-demand problem of all our water resources through a comprehensive plan and program. Flood control losses and requirements cannot singularly carry this "ball" alone, and as other water uses and supplies are developed the problems of flood control will diminish.

Within this State we have 20 major rivers upon which 95 to 99 percent of our flood damages occur. All of these rivers have watershed areas in excess of the 250,000-acre limitation placed on the Watershed Protection and Flood Prevention Act of 1954, being Public Laws 566 and 1018 as amended. Flood control on these rivers is, therefore, outside the scope of this act, excepting as qualifying tributary watersheds may be considered and work accomplished thereunder. The Corps of Engineers have investigated five of these major rivers and found that required flood control works are not economically justified at this time—these findings and decisions being based on general flood control benefits only.

Solution of our flood control problems may be brought about in the following manner:

1. Strive to continue our present level of "defensive maintenance" of existing works, banks, and channels;

2. More fully coordinate available flood control services and finances of Federal, State and local governments through education, planning, and carrying out works of improvement;

3. Collect new data and coordinate it with existing data regarding establishment of a standard level of protection required for each contiguous area and river basin as a whole;

4. More fully coordinate the activities and efforts of each special public and private water resource interest toward a common goal of comprehensive water resource development—project these interests and needs upon a common plane;

5. The State should (*a*) establish additional flood control zones (16 now exist), (*b*) take a more positive, aggressive action in its administration and enforcement of the existing law, and (*c*) revise and amend the law whereby its regulatory control may be exercised over all development of and make adjustments in structures and occupance on the flood plains (State's regulatory control now limited to flood control improvements and structures only);

6. More fully coordinate and consider other water resource interests when carrying out works of improvement or maintenance for a single interest, i.e. dredging for navigation is often most adverse to flood control works by aggravating erosion of dikes, banks, and upstream channel sections; and

7. Where a natural river channel is being used as an artificial irrigation water conveyor over many miles of its length the irrigation interests should be required to share in the cost of and should more readily accept the responsibility for the maintenance of that channel and artificial conveyor, i.e. Bureau of Reclamation irrigation projects on lower Yakima River.

ADDENDUM No. 6

PRELIMINARY COMMENT OF THE WASHINGTON STATE DEPARTMENT OF HEALTH RELATING TO THE INQUIRY OF THE GOVERNOR BY THE U.S. SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES

(These comments pertain primarily to the items of fundamental problems, municipal use, water recreation, and pollution abatement and use of water for waste disposal as listed in the committee's "General Outline of Procedures")

1. There is need for greater recognition of domestic use of water and protection of public health having highest priority in water resources development. It is noted that this is given prominence in the Senate resolution which established the committee. With all other uses, whether agriculture, industrial, wildlife, recreation, or power, there can be give-and-take and adjustments to aline with the concept of providing the greatest benefit.

2. There is a need for greater recognition of the increasing significance of quantities of water required for domestic and industrial use in the future.

3. More attention must be directed to water quality in water resources planning. The requirements for domestic and industrial supplies are becoming more exacting, while on the other hand the amount and complexity of water-contaminating materials is rapidly increasing. These contaminants may originate in sewage as is the case with detergents; they may occur in land

drainage as with fertilizers, insecticides, and other agricultural poisons; or they may be deliberately applied to water for plant or fish control.

4. There should be a unified program between those responsible for land and water resources development in instances where there will be intereffect of the uses.

5. There must be a greater recognition of the fact that our water courses are a necessary and integral part of the system for disposing of community wastes provided that all reasonable and practical methods have been employed to minimize the deteriorating effects of these wastes. This becomes necessary because many activities essential to the productive economy of an area, including community living, industrial operations, and agriculture and resource development result in the creation of waste products which become sources of water pollution, and the complete control of the effects of these wastes on the receiving waters by treatment prior to discharge is often financially and technically prohibitive. This may require in water resource development projects an allowance for certain sustained minimum flows.

6. Geological and topographical conditions in certain areas of the State of Washington are not generally favorable for obtaining large dependable yields from wells, or are such that development of surface supplies is favored because of lower cost of development. Accordingly, about 63 percent of our urban population is served by surface sources. An approximate classification of public water supplies as to source and population served is given in the following table:

Source	Number of supplies in the State	Population served	Percent of population served
Untreated ground water	280	305, 000	14
Treated ground water	68	460, 000	21
Untreated surface water	75	45, 000	2
Treated surface water	136	1, 390, 000	63

7. As is generally true over the United States, the bulk of the municipal systems are relatively small. In the State of Washington more than 90 percent of the systems are for communities of less than 10,000 population. It is to be recognized that for these small systems it is difficult and often impractical to attain any competence and reliability for operation of complex water treatment facilities. Accordingly, to assure safety, emphasis must be placed on maintaining high quality in the source of supplies.

8. Municipal use rates in our arid regions have reached a peak of 1,000 gallons per capita daily. This, in combination with population increases, has resulted in a 400-percent increase in total demand in just a few years, in some communities.

9. It is estimated that the investment in plant and equipment for municipal waterworks systems in this State is over $300 million and that we can look for an expenditure of another $200 million in the next 15 years for the development of additional sources and transmission.

10. The total annual "value of the product" of the waterworks industry in the State is upward of $20 million.

ADDENDUM No. 7

(Submitted by pollution control commission)

FIRST PHASE—DEVELOPMENT OF TECHNICAL BACKGROUND FOR COMMITTEE REPORT

I. STATEMENT OF THE EXISTING SITUATION AND PRESENT TRENDS, BY REGIONS

C. Fundamental problems

The fundamental problems from the pollution control standpoint are in general related to the water uses, quantity of water required and quality necessary to adequately sustain the constantly growing requirements of the economy of the State. Recognition of all legitimate water uses peculiar to a particular area and maintenance of adequate water quality to support those uses are the basic tasks of the pollution control commission.

The present trend in Washington is to evaluate the waters of State area by area, establish the water uses, prescribe water quality standards necessary to sustain those uses, and monitor the waters at frequent enough intervals to insure complianace.

E. Water use of pollution abatement

The commission has the authority by law to adopt, prescribe, and promulgate rules, regulations, and standards consistent with known, available, and reasonable methods of preventing pollution. If, after the aforementioned known, available, and reasonable methods of preventing pollution have been fully utilized, municipal and industrial wastes can then be discharged to the waters of the State. Reducing the effects of a pollutant by dilution in the receiving waters is resorted to only as a temporary expedient pending development of adequate methods of treatment.

II. PROJECTIONS OF FUTURE DEMANDS FOR WATER AND WATER RELATED ACTIVITIES CONSIDERING RELATIONSHIPS OF AVAILABILITY AND COSTS (SUPPLY-DEMAND RELATIONSHIPS)

D. Water needs of industries

Present industrial water usage in the State of Washington is approximately 1.2 billion gallons per day. Based on available water use data for the previous 10 years, the indicated industrial demand in 1980 will be about 2.2 billion gallons per day.

Present usage by major industry types is as follows:

[In million gallons per day]

Industry	
Pulp and paper	640. 0
Canneries, fruit and vegetable	34. 5
Milk processing	10. 0
Chemicals, oil, and metals	226. 0
Lumber	201. 5
Meat packing and related industries	9. 0
Mining, sand, and gravel	32. 0
Fish and shellfish; fresh and canning	8. 5
Fresh fruit and vegetables; packing	13. 5
Miscellaneous	36. 0
Total	1, 211. 0

J. *Trends in use of water for waste disposal*

The use of State waters for dilution of untreated wastes is decreasing steadily due to the development of new and improved waste treatment facilities, and to the policies of the pollution control commission. The trend is toward treatment that will provide discharged waste waters of a quality comparable to that of the receiving stream. This trend is much more evident in eastern Washington where water is at a premium due to lack of abundance and reuse demands.

III. MEANS OF MEETING FUTURE DEMANDS (NEW TECHNIQUES)

E. *Desalinization*

The projection of water needs to 1980 indicates that there will not be any shortages in Washington on a statewide basis. Area shortages, if any, can best be solved by transportation of water within the State, and will be far less expensive than desalinization installations.

F. *New techniques in multiple purpose river management*

The State of Washington is divided into 30 basins; each composed of a principal river and its tributary system. In 1959 the Commission began an intensive study of basin 19, the Chehalis River watershed. The study, when completed, will include the following: a complete inventory of all of the basin waters with extensive analyses of chemical, physical, biological and bacteriological characteristics; present water problems; present water uses; and the basin potential, including the projection of both municipal and industrial development. The completed study will serve as a very useful guide for multiple purpose water management in basin 19.

It is anticipated that similar studies for the remaining basins of the State will be jointly undertaken by all of the State governmental agencies having an interest in water management.

Cooperating agencies of the State have also embarked on a statewide water quality basic data program. Fifty-four surface water and 100 ground water stations have been established and are sampled at regular intervals. Analyses of samples are made by the U.S. Geological Survey on a matching fund basis. The accumulated continuous data on major streams and water-bearing aquifers of the State will provide constantly up-to-date information on water quality and quantity and will prove invaluable for water management purposes.

G. *Effects of nuclear energy*

Due to the abundant supply of hydroelectric power in Washington, it is not anticipated that power from nuclear sources will be developed in this State in the immediate future. However to provide long-range background information against the day when such installations become a reality, the waters of the State are being monitored regularly by radiological analyses as part of the basic data program.

SECOND PHASE—STAFF ANALYSIS OF TECHNICAL, ECONOMIC, AND OTHER FACTORS INFLUENCING THE NATIONAL INTEREST IN WATER DEVELOPMENT

II. WHO SHOULD DO WHAT

C. *Ways in which Federal agencies and others can help in meeting water needs*

The management of water resources within State boundaries is fundamentally a State responsibility. On the Federal level, assistance can best be provided by the following methods:

1. *Financial support.*—At the present time, direct financial assistance is provided by means of Public Law 660. Moneys received from this source have resulted in an expanded pollution control program in the State. Indirect assistance is presently being received via matching funds provided by the U.S. Geological Survey in the water quality basic data program. Expansion of financial support will permit additional personnel, facilities, and programs for an adequate administration of a water management program.

2. *Technical services.*—Many of the research needs in the field of water management are common throughout the country. For each State to provide complete research facilities for these needs entails unnecessary expenditures. Research centers such as the U.S. Public Health Service Sanitary Engineering Center at Cincinnati should be expanded and additional such centers established in other areas of the country.

ADDENDUM No. 8

STATE OF WASHINGTON,
DEPARTMENT OF FISHERIES,
September 17, 1959.

DEPARTMENT OF CONSERVATION,
Division of Water Resources,
335 General Administration Building,
Olympia, Wash.

(Attention: Mr. M. G. Walker).

GENTLEMEN: Receipt has been made of the letter from Senator Kerr to Governor Rosellini and concerning the work being done by the Select Committee on National Water Resources.

It is our considered opinion that the water requirements for all uses in Washington State by 1980 will be increasingly heavy and will thoroughly tax the supplies to meet the demands of the water users in this State. This statement is not without qualifications in that it is made with reference to existing legislation and the attitude of water utilization at a minimum of expense to the water users. Without question, there will necessarily be reservoir storage construction with mounting costs to the water user for formulating and placing into effect the methods of water conservation sufficient to meet the mounting demands.

Food fish, primarily salmon, production as a natural resource is the responsibility of the Washington Department of Fisheries. The existing fishery demand for salmon includes an average of 19,000 commercial fishermen and approximately 400,000 sport fishermen. The fishery resource requires sufficient clean waters in the streams of the State to provide for transportation water for fish passage, spawning, and initial rearing of these food fish stocks.

Reservoir storage and other means of conservation of water resources are acceptable to this department provided proper measures are included to sustain the existing fishery resource of the particular stream. If this may be impractical, from a fishery standpoint, other methods of restitution may be satisfactory such as supplanting the fishery resource of the stream system in question to another area or replacement in another manner.

To be specific, with direct reference to various points in the general outline of proposed procedures, consideration should be given to the following:

FIRST PHASE

I–E

At the present time, certain values are being assessed to the use of clean waters for dilution of polluted waters, sufficient to arrive at a water quality acceptable to the standards of maintaining and reproducing the fishery resource. Work and study are proceeding in this direction by the staffs in the department of fisheries and the pollution control commission regarding the quantities of harmful chemicals and wastes introduced to water bodies as well as BOD and oxygen content which may be acceptable and/or desirable for sustenance of fish life. Unquestionably these criterias will have to be finitely fixed, as some have been, to form the pattern to be followed and held at a rigid code. For specific criteria existing at the present time, refer to enclosure letter of January 7, 1958.

II–H

The department of fisheries direct relationship of sport fishery to water recreation is concerned with salt water areas. These are principally in the Puget Sound, the harbor areas, Straits of Juan De Fuca, and the coastal ocean area. Concerning fresh water recreation, with an increase of population, quite naturally there will be additional desires to create and commercialize more water areas. This department would have no objections to water use development providing the initial requirements for fish use areas.

II–I

Fishery demands for water on migratory streams will remain very much in the same category for the future as at present. These minimum requirements are for sufficient water to provide transportation for upstream and downstream migration; fish passage, either natural or artificial fish facilities to allow a maximum area use of the stream that may be possible; water and stream area to facilitate a maximum use benefit of stream spawning areas; sufficient water to maintain fry and fingerlings in the initial rearing stages. Not only does this apply to the quanity and controls for stream water, but also the quality of water to effectively conduct the reproductive cycle of these food fish.

III–F

The facts on record indicate that the heaviest consumptive use of water in the State of Washington is during the summer low-flow period. During the early portion of the summer, irrigation use sometimes is competitive with the early stage rearing of fish as well as downstream migration. During the late summer and early fall, the conflict is between the late irrigation interests and the start of upstream migration of adult fish and early spawning.

The solution of this problem, considering the excess of water supplies during the winter and spring seasons, appears to point toward wet season reservoir storage for utilization during the drier season of heavy consumptive water use. In order to logically support this type of planning, a multiple-use storage project would naturally be the most economical method of sustaining the water stocks. This in itself is a solution of many facets and functions requiring intensive study of water supplies, methods of storage, and beneficial uses which may be made of the water. Those who will benefit the most will have to be the major supporters of any storage project.

Each and every stream system will have to be surveyed for the particular requirements of stream storage possibilities balanced with average yearly water supplies and in turn summarized as to the economics for beneficial uses before determining the feasibility of any one project. This type of study should not be charted on only the requirements by 1980, but should initially be investigated for a maximum yield or potential.

SECOND PHASE

II–A

Federal participation should certainly be expected for any stream or watershed which experiences extremely high water runoff conditions. The basis for participation would be to provide flow-control measures.

The Corps of Engineers would certainly be expected to also participate in any instances where the concern is for navigation uses and/or heavy industrial development.

II–B

Non-Federal development may be all or in part and must be judged strictly on the benefits of the particular project. It can only be expected that the groups who will benefit the most to carry the major cost of the projects. This judgment is based on consideration of existing legislation regarding Federal or State assistance for particular types of projects. In speaking of multiple-purpose projects, it is natural to assume several participating agencies and individuals will be involved.

Very truly yours,

MILO MOORE, *Director.*

JANUARY 7, 1958.

STATE POLLUTION CONTROL COMMISSION,
Mr. EARL COE, *Chairman*,
Mr. JOHN BIGGS,
Dr. BERNARD BUCOVE,
Mr. JOSEPH DWYER,
Olympia, Wash.

GENTLEMEN: As suggested at the pollution committee meeting of December 4, 1957, I hereby submit for your consideration criteria for the allowable limits of pulp liquor and other wastes that may be released into public waters of the State without causing serious harmful effects to food fish, shellfish and other marine resources.

Coinciding with the criteria previously established by the commission for oils, domestic, and other waste, I believe that effort should be continued to find new and better ways of measuring and detecting all forms of materials polluting the waters of the State.

My attention has been called to the possibility that toxic waste in gases and trace substances are detected on public waters traceable to industrial waste for which no adequate means for measurement has been found.

It is possible that trace substances contained in the polluting materials now being released into public waters are contributing to environmental changes affecting aquatic life.

It is further suggested that the commission consult the applied fisheries laboratory at the University of Washington to discuss the possibility of tagging minerals found in industrial waster for the purpose of determining the absorption of the same by marine animals, plants, and organisms.

I urge your consideration of the criteria established by the Washington State Department of Fisheries in the granting of permits for the release of waste materials into public waters.

Along with the recommended formula for establishment of these standards, I am enclosing statement and recommendations of biologists employed by the fisheries department who have considerable knowledge and experience associated with this problem.

Very truly yours,

MILO MOORE, *Director*.

The department of fisheries establishes the following criteria for determining the maximum amount of pollution to be tolerated in the public waters of the State of Washington with the purpose of safeguarding the interest of the public in its fisheries and shellfish resources and hereby recommends the same to the State pollution control commission.

Tolerances

(*a*) That no person, firm, or corporation shall discharge or cause to be discharged into public waters any foreign matter or material that may, directly or indirectly, have any harmful or toxic effect upon fish or shellfish or upon the organisms upon which such fish or shellfish subsist except as hereafter described.

1. That no person, firm, or corporation shall be permitted to release waste as solids or materials in solution, either organic or inorganic, into public waters in any concentration that by actual test (independent of natural materials in the waters) retards or obstructs the growth, the survival, the feeding or the migration of food fish or shellfish. In the case of sulfite waste liquor the concentration shall not exceed three parts per million, based on the dilution of sulfite waste liquor containing 10 percent solids in normal sea water, beyond one-half mile from the point of discharge.

2. That no waste or pollutant, described in section (*a*) above, be discharged into public waters of the State that may directly or indirectly cause the dissolved oxygen content of such waters beyond a quarter-mile radius from the point of discharge to be reduced below five parts of oxygen per million parts of water.

(*b*) That where waste materials pollute the public waters of the State or are found to be injurious to the public interest or have a tendency to collect and remain within any of the bays, inlets, lakes, rivers, or streams of the State, the pollution commission in the name of the State shall notify those responsible to provide such waste disposal or purifying facilities necessary to comply with section (*a*) above and to insure that emergency measures are carried out to barge or pipe or otherwise dispose of such wastes by transfer to other areas authorized by the pollution commission where its diffusion into public waters will not be harmful to the public welfare. In event the polluters fail to act in accord with the directives of the pollution commission within a reasonable time they shall be subject to the penalties provided by law.

(*c*) That no waste, debris, or polluting materials, organic or inorganic, be released into the public waters of the State that will in any way be harmful to ducks and other wildlife, obstruct navigation, or have harmful effects upon vessels, boats, pleasure craft, or upon marine or fresh-water gear, nor increases the turbidity of the natural waters.

(*d*) That persons who control areas used for the booming or storage of logs, for anchorage or for other industrial activity be required to drag their respective areas at least once every 3 years to remove bark, logs, derelicts, and other debris which may be deposited in streams, lakes, bays, or harbors of the State.

(*e*) That the testing or sampling of public waters taken for the purpose of determining the concentration of the polluting substance or of measuring the dissolved oxygen content of waters affected by pollution, shall be taken at the surface if such materials appear to be more buoyant than the natural water, or from the bottom strata in areas where waste appears to be heavier than the waters affected, or within whatever strata that contains the maximum concentration of the polluting materials.

ADDENDUM NO. 9

THE EFFECT OF WATER USES ON FISH AND GAME PROTECTION

(Submitted by the Department of Game, State of Washington)

The State of Washington Department of Game is charged with the responsibility of managing, propagating and protecting the game animal, game bird and game fish populations of this State. This responsibility to some 550,000 license holders requires this agency to be aware of the problems concerned with our natural resources that may affect the production of these game animals, game birds, and game fish. The water supply of our State is one resource upon which our fish and game management program is extremely dependent.

Hunting and fishing is one of the most important resources in the State of Washington. License holders spent some $68 million in 1954 in pursuit of their favorite game animal, game bird or game fish. Present day costs and increased numbers of license holders increase this figure conservatively to $83,600,000 annually. This figure represents an expenditure of $152 per resident license holder annually.

We are concerned with several fundamental problems pertaining to water uses. These are:

1. Maintenance of an adequate water supply in our lakes and streams for propagation and rearing of both resident and anadromous species of game fish.
2. Maintenance of adequate water supplies for sustenance of our game animal and game bird populations.
3. Prevention of fish losses in streams due to artificial blocks to migration of anadromous species and due to lack of adequate provisions for screening water diversions.
4. Prevention of pollution to our lakes and streams that will reduce habitat for our fish and game.

We are particularly concerned with the granting of excessive numbers of water rights on lakes and streams that do cause loss of habitat for our fish and game. The present lack of adequate inventory procedures on our waters makes adequate restrictions for prevention of overuse of water nearly impossible.

The problem of multiple water uses is becoming more acute each year. Present trends appear to be toward greater water use by irrigation users, industry, and power interest. Unless fish and game are given a fair share of the water supply of the State of Washington it will be impossible to maintain the value of this resource.

The use of water for pollution abatement could be a benefit to our game fish resources in this State. However, it would appear to be a much better plan to restrict the amount of pollution and use the water allotted for this specific purpose for other beneficial uses.

The use of water for recreational purposes is expanding tremendously. More leisure time by the average worker leaves him more time to enjoy the recreational opportunities offered by our lakes and streams. The increasing number of fishermen that use our waters increases the problem of maintaining adequate supplies of fish for them to harvest. Not only is the available area for fish production going to be in short supply in the future, but so is the money necessary to provide more fishing for greater numbers of fishermen. Our present management policy which involves lake rehabilitation permits us to provide the maximum fishing for the majority for the least cost. However, to enable us to keep up with the increased pressure from the fishing public, we must protect our water supplies. The increased demand for water from our lakes and streams reduces the available habitat needed for fish production. Therefore, it becomes more difficult to keep pace with the expanding fishing public.

Our game animal and game bird populations are also dependent upon water supplies and reduction of these supplies will affect the production of these game species.

The solutions to the problems pertaining to multiple-purpose river management will be required if we are to maintain the fish and wildlife resources of our State. It would appear that one of the first objectives of planning for the future should be a careful analysis of our stream flows and an inventory of our present water uses so that a sound program can be planned. If we knew how much water we had in each stream during the critical low-flow periods and knew exactly what our uses were for each stream, then low-flow requirements for nonconsumptive uses could be determined and greater beneficial uses could be obtained from available waters.

The question of who should be doing the work pertaining to solving the water-use problem in our State is an important one. Most certainly, all of the work cannot be handled by one group. A careful analysis should be made to determine which of the various Federal and State agencies would be the most concerned with specific phases of the entire program and then the responsibilities divided so that all interested groups would have an equal share in developing a progressive program to develop the maximum benefits from one of our greatest natural resources, water.

WEST VIRGINIA

State of West Virginia,
Executive Department,
Charleston, January 11, 1960.

Mr. Theodore M. Schad
Staff Director, National Water Resources Committee,
U.S. Senate, Washington, D.C.

Dear Mr. Schad: Your recent letter to Mr. Swiger has come to my attention. Mr. Swiger is no longer with this office.

I regret very much that we had overlooked this material. I am sending a report "Water Resources of West Virginia," which gives the status of the water-pollution control and water-resources programs currently as well as the plans for the future. I hope this is not too late to be of use to you and the committee.

Very sincerely,

Cecil M. Underwood, *Governor.*

Water Resources of West Virginia

The State water resources commission was created by the 1959 session of the legislature, effective June 9, 1959. The act creating the new agency, in effect, broadened the powers of the now extinct State water commission into the field of water resources development. The old agency was a stream pollution control agency only. The law in respect to stream pollution control remained unchanged but, in addition, the new agency was given authority to "formulate comprehensive plans and recommendations for the further development, improvement, protection, preservation, regulation, and use" of all the water resources of the State, including surface and subsurface waters, natural and artificial watercourses, lakes, and ponds.

The newly created commission has not yet conducted any studies of the water resources of the State nor has it made a study to determine how it will administer the new law. No State funds were appropriated for this purpose. The budget of the water resources commission remains the same as that of the old water commission which was charged with stream pollution control only.

Of course there are certain things which, although they are parts of the stream pollution control program, will serve as starting points for the comprehensive development of the State's water resources. These include the systematic programing of the municipal and industrial waste control facilities, the measuring of water quality criteria, and the cooperative gaging of streamflows with the U.S. Geological Survey.

A legislative subcommittee on water resources has been making, for the past several months, a basin-by-basin survey of stream pollution conditions. No reports have been made available to this commission regarding their findings and recommendations.

Any statements made at this time regarding the types of water uses and amounts used would be strictly guesswork. Some figures were collected some years ago on the amounts of industrial and municipal water used but the figures were admittedly incomplete at the time of the study and are so badly out of date now as to make them useless.

The following points have been suggested for the initial phases of a water resources development program:

1. Make a study of present and potential water uses in West Virginia.

2. Continue along already established lines a broader cooperative program with the U.S. Geological Survey and the U.S. Weather Bureau for the measurement and dissemination of data in regard to precipitation and runoff.

3. Classify streams into zones according to present water quality and present and potential uses.

4. Establish a water quality monitoring network, including radioactive background monitoring.

5. Set up a laboratory capable of detecting radioactivity in water.

6. Choose a watershed for a trial water resources development program and coordinate stream pollution control activities to fit the program.

7. Approach the State on a basin-by-basin water resources development program.

8. Work cooperatively with soil, forest, and other conservation agencies, as well as all other interested groups, insofar as their programs affect water resources.

9. Continue to cooperate with the U.S. Public Health Service, the Corps of Engineers, and other Federal, State, and local agencies on problems of mutual concern.

In the development of any water resources program, cognizance must be taken of the fact that streamflows vary widely between flood and drought. The smaller streams, in particular, are subject to damaging flash floods. These small streams may go completely dry in summer months.

Present pollution problems facing the commission may be classed as municipal, industrial, coal washing, mine drainage, and strip mining. These are separated for administrative purposes.

Municipal sewage presents a problem since many cities, in order to abate pollution, must not only build a treatment plant but must also extend and rehabilitate the existing sewer system. This adds an extra financial burden which produces a real hardship in many cases. Federal grants-in-aid have stimulated the construction of municipal sewage treatment facilities in West Virginia.

Pollution in West Virginia streams arising from industrial establishments may be listed as follows:

1. Color and sediment arising from such industries as coal washing, tanning, paperboard and paper box and bag manufacturing, stone washing, and textile dyeing.
2. Biochemical oxygen demand from chemical and synthetic textile plants, slaughterhouses, canneries, milk processing plants, and tanneries.
3. Taste and odor from chemical plants and byproduct coke plants.
4. Oil from refineries, bulk stations, railroad shops, pipelines, natural gas compressor, and drying stations and the metal industries.
5. Acids and alkalies from coal mining, steel mills, and chemical plants.
6. Toxic compounds from chemical and metal fabricating plants.
7. Dissolved solids, hardness, and heat from many types of industries.

These are being attacked but progress is slow and costly.

South of the Kanawha River coal washery wastes constitute practically the only form of industrial pollution. New sources are readily handled. However, the problem is securing abatement from those which were in operation prior to the establishment of a permit system in 1953. At our present rate of progress, all of the approximately 200 coal washeries should have clarification facilities constructed within the next 2 years.

The problem of acid mine drainage has been considered by many to be West Virginia's most serious stream pollution problem. Hundreds of miles of watercourse have been ruined by acid drainage from deep coal mines and strip pits. The problem is most prevalent in the northern part of the State. A control program has been proposed by the Ohio River Valley Water Sanitation Commission and should it be adopted, West Virginia will cooperate as fully as possible.

Increasing public concern is being raised over stream pollution from strip mines. The problem of enforcement is made more difficult by the fact that in order to control this type of pollution, the operation of the strip pits themselves must be controlled. Since other agencies are involved and since the laws and regulations governing strip mining appear to be rather loose in terms of conservation, the problem is quite complicated.

It is possible to foresee that between now and 1980 the accent on pollution control will shift from coal washing, municipalities, and industrial plants to mine drainage and strip mine control, unincorporated areas, and individual householders. By that time a full-fledged water resources development program should have been in full operation for several years with some accomplished jobs to show for its existence.

Annex 1. West Virginia Code, chapter 20A and chapter 16, article 11. "Water Resources and Control of Water Pollution" (not printed).

Annex 2. "Report of Progress, 1957–58," State of West Virginia, State water commission, Charleston, W. Va. (not printed).

WISCONSIN

PUBLIC SERVICE COMMISSION OF WISCONSIN,
STATE OFFICE BUILDING,
Madison, Wis., August 20, 1959.

Hon. ROBERT S. KERR,
U.S. Senator,
Chairman, Select Committee on Water Resources,
Senate Office Building, Washington, D.C.

DEAR SENATOR KERR: Governor Nelson has referred your letter of June 23, 1959, requesting information and comments concerning water problems to this commission for reply. The Public Service Commission of Wisconsin is charged by law with the regulation of levels and flow of waters in lakes and streams. In the preparation of these comments we have, with the Governor's approval, consulted with representatives of the conservation department, which is concerned with forests, fish and wildlife, the State board of health, which is concerned with water pollution and the public health, the department of industrial development, the attorney general, and others.

The information and comments requested are contained in the enclosure herewith under the following headings:

1. Wisconsin water problems—present and anticipated up to 1980.
2. Views as to the solution of Wisconsin's water problems.
3. Comments on subjects in outline of proposed procedures for staff work of the national water resources committee.
4. Views on matters mentioned in Senate Resolution No. 48.

Also enclosed is a copy of the 1959 report of the Wisconsin Legislative Council on Water Resources. This report summarizes the extensive work by the water resources committee of the legislative council assisted by the natural resources committee of State agencies in the field of water law.

If you wish further information or comment on any of the subjects, please let us know.

We would appreciate notification of the times and places of public hearings on committee proposals, if such hearings are held, in order that representatives of the State of Wisconsin may appear and be heard.

Very truly yours,

JOHN F. GOETZ, Jr., *Acting Secretary.*

WISCONSIN'S WATER PROBLEMS—PRESENT AND ANTICIPATED UP TO 1980

A. Problems concerning lakes and streams

1. Coordination and regulation of water use by different interests such as:

(*a*) Potable water supply for urban and rural use.

(*b*) Water supply for industrial processes and power.

(*c*) Pollution of lakes and streams by waste, sewage, and discharge of heated waters from riparian property, urban communities, industries, and water craft.

(*d*) Recreation involving bathing, boating, water skiing, aquatic plant control, hunting and fishing, shoreline improvements, and zoning of water uses.

(*e*) Fish and wild life propagation.

(*f*) Consumptive use of water for irrigation and by industry.

(*g*) Variations of levels and flow due to changes in precipitation and control of impoundments.

(*h*) Adequate public access.

(*i*) Improvement of channels, ports, and harbors for commercial navigation and control of shoreline filling.

2. Definition of local, State, and Federal areas of responsibility.

3. Increased program of surveys and measurement of the resource and increased research concerning its use.

B. Problems concerning underground waters

1. Preservation of adequate supply and coordination and regulation of water use by different interests such as:

   (*a*) Potable water supply for urban and rural use.
   (*b*) Water supply for industrial processes.
   (*c*) Water supply for irrigation.
   (*d*) Provisions for recharging aquifers.
   (*e*) Prevention of contamination.
   (*f*) Effect of withdrawal of ground water on natural springs and ponds.

2. Review and redefinition of individual, local government, and State government areas of control over the resource.

3. More adequate surveys of extent and characteristics of the resource and increased research concerning its use.

C. Problems concerning diffused surface waters

1. Improved control or diffused surface water in order to:

   (*a*) Limit the loss of agricultural land from erosion.
   (*b*) Minimize the silting of lakes and streams.
   (*c*) Avoid the creation of salt marshes or lands through retention of salt from highway ice control programs.

2. Coordination of State and Federal programs.

D. Problems concerning weather control

1. Prevent erratic or poorly planned weather modifications by cloud seeding or other methods which may be proven effective.

2. Determination and definition of individual, State, and Federal areas of responsibility.

VIEWS AS TO THE SOLUTION OF WISCONSIN'S WATER PROBLEMS

A. Problems concerning lakes and streams

The present Wisconsin law concerning waters in lakes and streams is essentially adequate and sound. These laws give primary recognition to the rights of riparian owners and allow reasonable use of the water by them and by the public generally. The administrative agencies of the State charged with administration of these laws are well acquainted with their responsibilities under those laws and are carrying out their programs in a satisfactory manner. The increased use of this resource calls for an accelerated program of research, surveys, and measurements in order that administration may continue to be effective.

The increase in the use of water in lakes and streams, including the heavy increase of recreational uses with associated improvements such as sand blankets, dredging and filling, and the correspondingly increased program of administration by State agencies, will call for increased appropriations to carry out that program. Changes in emphasis in different parts of the program will, from time to time, call for changes and amendments in the administrative law and rules to cope with the changed situations. Examples of such changes are those brought about by increased use of water for spray irrigation (which require careful permit control and strict enforcement to protect the public interest) even though Wisconsin is considered to be a humid State, and the increased interest in and necessity for port improvement and development resulting, in part, from the completion of the St. Lawrence Seaway and the connecting channels projects.

Because of expanding demands for water from the Great Lakes, Federal policy should be developed to state specifically how, and under what circumstances, water for domestic and other uses may be diverted from this source into adjacent watersheds. Such policy should include a requirement for return of this water to the Great Lakes after treatment for a high degree of purification.

The increased interest in, and use of, waters in lakes and streams has apparently stimulated the interest of the Federal Government in geographical areas where heretofore it has exercised little initiative. When Federal agencies enter into fields of activity heretofore handled almost exclusively by State agencies it becomes advisable to define and to periodically redefine the areas of responsibility of the State, local, and Federal Governments. Recent examples of increased Federal concern are Federal flood control projects on small streams, water pollution control on interstate streams and the requirement of a Federal Power Commission license for dams on very small streams, many of which dams were constructed when the land was being first occupied over a hundred years ago.

B. Problems concerning underground waters

Contrasted to the law of reasonable use, which prevails with respect to the lakes and streams of Wisconsin, until recently, the law of underground waters has been that the owner of the land had the right to unrestricted use of the underground waters. Within the last few years a law has been in force which protects the underground water supply used by a municipality from being interfered with by the development and operation of high-capacity wells owned by others. Presently, wells owned by persons or corporations other than municipalities have no protection from the effects of other wells owned by their neighbors, including municipalities. The Natural Resources Committee of State Agencies and the legislature have considered this problem over the past 8 years, but as yet, no further legislation has been enacted. It is believed further legislation should be enacted and administrative processes set up to carry out the new laws.

The underground water problems are becoming more pronounced. While they are presently the greatest in certain urban and industrial areas, there is an increasing use of ground water for irrigation in rural areas which will require attention. Here again additional funds will be required to make more adequate surveys of the extent and characteristics of underground waters in order that reasonable use of the resource may be assured through regulation by appropriate laws and administrative rules.

As yet, except for cooperative investigation of the resource, the Federal Government has not interested itself greatly in the underground waters of Wisconsin. It appears that this is a subject of local and State interest rather than of national interest, at least in the State of Wisconsin.

C. Problems concerning diffused surface water

The problems in this field all lead to the advisability of retarding the runoff of rainfall and, to a lesser extent, melting snow from the land. Retarded runoff has the triple advantage of restoring the ground water levels, minimizing the loss of valuable topsoil through erosion, and reducing the siltation of lakes and streams. The most effective means of accomplishing these purposes is through following well-known erosion control practices. A closely related activity is that of forest restoration in areas well adapted to forest growth and where soil erosion and rapid runoff will otherwise take place.

Both State and Federal agencies are active in this field and continual coordination of their programs is a necessity. Reforestation and soil erosion control are both appropriate subjects of Federal interest because of the great number of years necessary to develop a stand of merchantable timber and because of the essentially irreplaceable characteristics of our topsoil.

D. Problems concerning weather control

Privately sponsored corporations, as well as individuals, have been active in this field in other States with indeterminate results. It seems probable that progress will be made in weather control during the next few decades. Whenever weather control becomes feasible and appreciably effective, Federal regulation will become an absolute necessity. Weather control which may be good for one State may have an adverse effect on the neighboring States. Certainly the kind of weather that is good for one industry is likely to be bad for some other industry.

Wisconsin has a law requiring only the reporting of activities in this field. No other regulation has been undertaken. This regulation was intended primarily to obtain the facts which might become available from attempted weather control operations by cloud seeding. When, and if, weather control becomes effective, it must, in our opinion, be controlled by the Federal Government, if not, in fact, through international agreement. The clouds and wind currents are not respectors of State or national boundaries.

E. Summary of comments

To summarize our comments on Wisconsin's water problems, it is our opinion that most of these problems hinge on what is the reasonable use of the resource by the individual, or other private interest, which will not infringe on public rights or unduly interfere with the public interest. For the most part the solution of these problems can be handled on a State or local level under present or modified laws and administrative rules. The

Federal Government need interest itself only when inaction by State or local governments will result in an irreparable loss to the public or unreasonable damage to the people of a neighboring State. As a general principle, projects which are of purely local or State interest should, in our opinion, be financed by the State and the locality. The Federal Government has no source of tax revenues other than those extracted from local taxpayers.

On such things as subsidies for land drainage, Federal agencies should be coordinated so they do not spend money on projects which oppose the programs of other Federal agencies. In the past there has been a lack of such coordination among Federal agencies. Also, the Federal Government should not engage in acts contrary to State policy. In fact, there should be no Federal moneys advanced to foster projects not authorized and approved by the State.

COMMENTS ON SUBJECTS IN OUTLINE OF PROPOSED PROCEDURES FOR THE STAFF WORK OF THE NATIONAL WATER RESOURCES COMMITTEE

Each of the subjects in the outline is of importance. However, we will comment briefly only on those subjects which seem to pose particularly important or new problems for investigation.

FIRST PHASE—DEVELOPMENT OF BACKGROUND

I–A. Summary of water resources available

Our comment on this subject is related to item II–C of the second phase, namely ways in which Federal agencies and others can help in meeting water needs. It is probable that when the summary under first phase I–A is prepared, the committee will conclude that a great deal more work must be done to complete anything like a comprehensive inventory of underground water resources available. It is also probable that you will find a dearth of inventory information on the flow in small surface streams in different areas. We have found in most cases the decision in a particular case of proposed water use depends on the water resources available at the immediate geographic locality of the proposed operation, whether the proposal be to use a small stream or underground water.

The U.S. Geological Survey, in cooperation with the different States, has obtained considerable information on streamflow, particularly on larger streams, but much less information on small streams and very much less on the available underground waters in particular localities. For example, the limitations on the use of underground water in any particular urban area must usually be determined in that particular area rather than from generalized knowledge of the character and general extent of the aquifer from which the underground water is to be drawn. The necessity of obtaining this type of information is not generally understood by the layman or by legislators, and promotional activities by the Federal Government in obtaining this sort of information through cooperative procedures is most important.

II–C. Agricultural use of water

During the last several years there has been considerable promotional work to encourage the humid States east of the Mississippi River to adopt some modified form of the western water law of prior appropriation in lieu of the present law based primarily on riparian ownership and public rights to the use of public waters. We are of the opinion that this sort of promotional work in the humid States by Federal agencies is inadvisable for the reason that the riparian type of law with suitable modifications for local application is better suited to the humid States than a law of prior appropriation. This is true because of the more extensive use of the streams in the Eastern States for recreation, fish and wildlife, navigation and use by the public generally. The resort industry of Wisconsin, for example, depends largely on the use of lakes and streams untrammeled by prior appropriation restrictions. Likewise, the use of small streams for the watering of stock and other urban, industrial, and general agricultural uses by all of the people should not be limited by prior appropriation by a comparatively few agricultural developments.

II–G. Flood control

Many of the flood-control problems are created by the construction of buildings and other improvements in the natural flood plain of streams regularly subject to spring freshets. County and other local governments apparently are reluctant to adopt zoning ordinances which prohibit the construction of buildings in the natural flood plains of the different streams. Promotional work by the State and Federal governments to encourage such zoning would not only limit the damage created by floods, but would reduce the tendency toward Federal expenditures for flood control necessitated by unwise industrial and urban developments within flood plains. Encouragement of the establishment of "conservancy districts" for recreational use zoning of flood plains should be increased.

III–C. Weather modification (induced precipitation)

We are of the opinion that this is a field where work by Federal agencies would be particularly appropriate and helpful. The subject is one of national, if not international, significance. No single State is in a position to determine the effectiveness of weather-control measures nor the results achieved or created by weather modification procedures. Neither is any State in a position to regulate water-modification activities so as to insure beneficial results to the greatest economic benefit of the public without seriously and adversely affecting other large segments of that public. If effective weather-control techniques are developed and used, there appears to be an enormous field for public benefit, but also a likelihood of endless litigation between groups or segments of the population who are damaged by rainfall which is beneficial to other groups. Such litigation would, in all likelihood, arise between groups in different States, if not between different nations. The Federal Government should certainly take the lead in this field of research development and regulation.

SECOND PHASE—STAFF ANALYSIS

II–C. Ways in which the Federal agencies and others can help in meeting water needs

The Federal Government can be most helpful in pursuing the lines of research and factfinding followed by the Weather Bureau, U.S. Geological Survey, Soil Conservation Service, and perhaps a few other agencies insofar as they concern themselves in those necessary activities which would not likely be adequately pursued by all State and local governments. The results of such research and factfinding activities should be made available to all interested persons through appropriate publications and promotional activities. Grants-in-aid from the Federal Government and subsidies to carry on those programs which the State and local governments can well carry on themselves should be avoided wherever possible. Once a Federal appropriation has been made for such grants-in-aid, every State must take advantage of those grants or it finds its citizens paying Federal taxes to support such activities without benefit. It should be borne in mind, in all activities, that the only source of funds is the individual taxpayer and that there is no source of Federal funds which does not have an impact on that taxpayer's resources.

VIEWS ON MATTERS MENTIONED IN SENATE RESOLUTION NUMBER 48

Section 3 of this resolution outlines in general terms the tasks and duties of the committee. Subsection (b) of section 3 charges the committee with recommending the character of legislation to accomplish a number of things with respect to the water resources. Presumably it is inferred in this charge that the recommended legislation will indicate at what level of government the different promotional and development activities should take place, whether at Federal, State, or local governmental levels. It seems to us most important that the committee recommend for Federal legislation only those matters of true Federal or national concern and that it recommend for State consideration and possible legislation those matters which can be handled adequately by State and local governments. The State should have paramount control over the destiny of its purely intrastate lakes and streams to the end that State water policy cannot be upset by dam-building permits granted by any Federal agency. Only in this manner can responsible State and local governmental responsibilities be maintained. The strength of our Nation lies in the strength of its State and local governments, in the will of its individual citizens and in the general guidance and coordination of the Federal Government.

WYOMING

WYOMING EXECUTIVE DEPARTMENT,
Cheyenne, September 28, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: I am enclosing a statement of views and summary of Wyoming's water resources for the Senate Select Committee on National Water Resources as requested in your letter of June 23 in which you established a deadline of October 1.

With every good wish,

Sincerely yours,

J. J. "JOE" HICKEY, *Governor.*

STATEMENT OF VIEWS AND SUMMARY OF WYOMING'S WATER RESOURCES FOR SELECT COMMITTEE ON NATIONAL WATER RESOURCES

Wyoming, from the time of its designation as a Territory, has realized the value of its water resources and, when it became a State in 1890, the Constitutional Convention and the first State legislature was fully aware of those values and wrote into our constitution and laws a code for the use, control, and distribution of the waters of this State. In the preparation of this water code, they were fortunate to have had the very able counsel and assistance of Elwood Mead, then Territorial engineer, later the first State engineer, who many years later also served as commissioner of reclamation.

Conservation and use of water for irrigation is of the greatest importance in this State and irrigation of agricultural lands has been practiced since the time it was first settled by the early pioneers. This development of irrigation in Wyoming has proceeded by individual farmers and ranchers, partnerships, ditch companies, and irrigation districts. In 1904, the Reclamation Service, now the Bureau of Reclamation, entered the area and started construction of the larger projects such as the Shoshone project and the North Platte project.

The State of Wyoming, you will note, is situated on the headwaters of four of the major river basins of the Western United States. Water leaving the State flows to the Pacific Ocean, the Great Salt Lake, the Gulf of California, and into the Gulf of Mexico.

About 75.6 percent, or 73,680 square miles, of the area of Wyoming lies in the drainage basin of the Missouri River. This area is drained by the Yellowstone River, the Clarks Fork of the Yellowstone, the Big Horn River, the Tongue and Powder Rivers in the vicinity of Sheridan and Buffalo; the Little Missouri River and the Belle Fourche River in the northeastern part of the State; the Cheyenne River and Niobrara River in the east central part; and the North Platte River, which largely drains the southeast part of Wyoming. A small area around Cheyenne and southeast of Laramie contributes to the flow of the South Platte River.

The Green River and the Little Snake River in southwestern Wyoming are on the headwaters of the Colorado River drainage basin, which covers 17.5 percent, or more than 17,000 square miles, of the State's area. The runoff of these streams constitutes our contribution to the Colorado River.

The Bear River in southwestern Wyoming wanders from Utah to Wyoming, then back into Utah, then back again to Wyoming, and then at Border leaves Wyoming to flow through southeastern Idaho back again to Utah and into the Great Salt Lake. This river basin includes 1.5 percent, or 1,490 square miles, of the area of Wyoming.

Snake River in Jackson Hole and Salt River in Star Valley join to flow westerly across Idaho into the Columbia River. This drainage basin covers about 5.4 percent, or 5,256 square miles, of the State.

In quantity of streamflow, Snake River is Wyoming's largest river, with the Wyoming area contributing a flow of about 5 million acre-feet of water annually. This water comes from the runoff of the high mountains of the Jackson Hole and Star Valley areas. Yellowstone River, as it leaves Yellowstone National Park, has an average annual flow of over 2 million acre-feet. The Big Horn River, as it flows north into Montana has an average annual discharge of about 2,400,000 acre-feet. Green River, where it leaves Wyoming, has a normal yearly runoff (25-year period, 1921–45, defined as normal) of about 1,426,000 acre-feet and the North Platte River at the Nebraska-Wyoming State line has an annual flow of about 1,600,000 acre-feet, exclusive of amounts crossing the line in canals of North Platte project.

Wyoming streams produce a mean annual runoff of about 15 million acre-feet and at the present time it is estimated that we are depleting this supply by about 2,500,000 acre-feet by using and reusing this water for beneficial uses. With more complete development, this consumptive use will probably be increased to about 4 million acre-feet. Adjoining States have established some equities in this water and on several streams we are limited either by court decrees or by compacts in the amount we can utilize.

The average annual water supply does not present a complete picture for the conservation and development problems since there are wide variations in yearly flows and in seasonal flows. Adequate storage facilities must be provided to carry over water from years of high runoff to years of low runoff and also from the periods of heavy spring flows so as to make water available late in the irrigation season and for municipal and industrial use during the entire year. The flow must be leveled out to make it available when needed.

The greatest water use in Wyoming today is for irrigation purposes and we are actually irrigating about 1,700,000 acres of land. The acreage having adjudicated water rights totals about 2,750,000 acres. Hydroelectric power is produced principally by release of water stored for irrigation use.

Although the major irrigation and hydroelectric power projects in our State have been constructed by the Bureau of Reclamation, they constitute only about 300,000 acres of the total lands irrigated. Individuals and private enterprise have developed over 1,100,000 acres and companies which operated under the Carey Act some 200,000 acres. Some 30,000 acres have been developed by the U.S. Indian Service.

In addition to the surface water resources in Wyoming, it has been found from investigation and development that there is a very considerable ground water resource, the full potential of which is to a large extent undetermined. Under a dollar-for-dollar cooperative program with the U.S. Geological Survey, the State Engineer's Office, since about 1940 (and more recently the Natural Resource Board), has carried on investigations and studies of ground water resources in Wyoming, principally in the southeastern part of the State, with some less detailed investigations in other areas.

Greatest development up to the present time has occurred in the Pine Bluffs area of eastern Laramie County and in the Cheyenne area. About 15,000 acres of land has been irrigated from wells in the Pine Bluffs-Carpenter area. The city of Cheyenne has, during the last few years, developed the greatest part of its municipal supply from wells in the area west and northwest of the city. Investigations have shown that a large quantity of ground water can be developed along the North Platte River Valley in the areas near Torrington and Lingle. A number of deeper wells in the Wheatland area have also been very successful but are quite expensive to drill and equip. Such water supplies in the Wheatland area are supplemental to the Wheatland project. Studies have also been carried on in other parts of the State and some areas give considerable promise.

Federally constructed projects

Federal projects constructed in Wyoming by the Bureau of Reclamation began with the construction of the Shoshone project near Cody and Powell. This project was originally proposed by Col. W. F. Cody ("Buffalo Bill") and Nate Salsbury in 1899, but they ran into difficulties in financing it. The project was authorized on February 10, 1904, and construction began in May of that year. Since that time, additional units or divisions have been added from time to time and further extensions are proposed for the future. It now consists of the Buffalo Bill Dam and powerplant in the Shoshone River Canyon west of Cody, Wyo. The reservoir has a present capacity of 439,850 acre-feet and the powerplant an installed capacity of 5,600 kilowatts, a 5,000 kilowatt power installation at the Heart Mountain plant, the small Ralston Reservoir, the Garland, Frannie, Willwood, and Heart Mountain Canals and distribution systems for the irrigation of 96,000 acres of land.

Construction of the Riverton project on the ceded portion of the Wind River Indian Reservation was started in 1920. Wind River and its tributaries provide the water supply and storage is provided to a capacity of 152,000 acre-feet at the Bull Lake Reservoir on Bull Lake Creek and at Pilot Butte Reservoir, an off-stream reservoir with capacity of 36,960 acre-feet. The Wyoming Canal diverts at the Wind River Diversion Dam for the irrigation of about 100,000 acres of land north and east of Riverton. An 1,800-kilowatt powerplant is installed at Pilot Butte Reservoir and the Pilot Canal diverts at that point.

Boysen Dam at the head of Wind River Canyon was completed in 1952 and creates a reservoir with a capacity of 820,000 acre-feet at the normal operating pool with superstorage of 673,000 acre-feet for control of floods. A powerplant with installed capacity of 15,000 kilowatts is located at the dam. Regulating the flow of the river will provide additional irrigation development both upstream and downstream. In addition, Boysen Reservoir reduces flood flows to safe channel capacity, retains a large volume of silt, provides a great improvement in fish and wildlife habitat and makes possible expansion of recreational opportunities.

The Hanover-Bluff unit provides for the irrigation of 7,400 acres of new land in the vicinity of Worland, Wyo., by enlarging the upper part of the existing Upper Hanover and Bluff Canals from the Big Horn River and installations of pumping plants to cover lands above those canals.

Owl Creek unit consists of the completed Lucerne pumping plant on the Big Horn River north of Thermopolis, Wyo., and the Anchor Reservoir on the South Fork of Owl Creek, now under construction. The purpose of this development is to provide supplemental water to some 18,000 acres of presently irrigated lands.

The North Platte River is probably the most completely regulated stream in the United States and on this stream the Federal projects consist of the North Platte project and the Kendrick project. The North Platte project includes Pathfinder Reservoir, completed in 1909, with a capacity of 1,045,000 acre-feet, the Guernsey Reservoir, completed in 1927, with a present capacity of about 45,000 acre-feet, Lake Alice and Lake Minitare, along the Interstate Canal in Nebraska, the Whalen diversion dam and the Interstate, Fort Laramie, and Northport Canals. The project provides for the irrigation of approximately 70,000 acres of land in Wyoming and 170,000 acres in Nebraska, in addition to furnishing storage water under Warren Act contracts to a large acreage in both States. A powerplant of 4,800 kilowatts is installed at the Guernsey Dam and there also is a small plant near Lingle.

The Kendrick project includes Seminoe Reservoir, on the North Platte River, with a capacity of 1,012,000 acre-feet, the Alcova Reservoir, with a capacity of 190,500 acre-feet, and the Casper Canal diverting from the Alcova Reservoir. A 32,400-kilowatt electric powerplant is installed at the Seminoe Dam and a recently completed powerplant at the Alcova Dam has an installed capacity of 36,000 kilowatts. On this project, water must be carried over from years of high runoff to provide a dependable supply. About 18,000 acres are now irrigated.

Under the Missouri River Basin project, the first unit completed was the Kortes dam and powerplant of 36,000-kilowatt capacity located on the North Platte River between Seminoe and Pathfinder Reservoirs. Storage capacity is only 4,800 acre-feet. This powerplant utilizes storage release from Seminoe Reservoir which is in part recaptured at Pathfinder.

Recently completed under the Missouri Basin project is the Glendo Dam on the North Platte River near the town of Glendo, which creates a reservoir of 800,000 acre-feet capacity of which 100,000 acre-feet is for irrigation storage, 275,000 acre-feet of flood control capacity, 115,000 acre-feet for sediment control, and 310,000 acre-feet for power storage and reregulation. Included in this unit is the Fremont Canyon powerplant, now under construction, to utilize the power head available at Pathfinder Reservoir and that in the river above the high-water line of Alcova Reservoir by the installation of a powerplant of 48,000-kilowatt capacity. The powerplant at Glendo Dam will develop about 24,000 kilowatts of power and will be operated principally during the irrigation season. The purpose of Glendo Dam is the reregulation of upstream storage releases, flood control, sediment control, supplemental irrigation, and benefits to recreation and sanitation by allowing a more uniform year-round streamflow in the section of the river from Alcova to Glendo.

Construction is about to start on the Gray Reef Dam, located a short distance below Alcova, to reregulate the power releases at Alcova to a uniform flow necessary for irrigation, pollution control, and fish and wildfowl.

In addition, the Bureau of Reclamation has constructed the Keyhole Dam on the Belle Fourche River near Moorcroft, Wyo., with a capacity of 340,000 acre-feet, of which 140,000 acre-feet is for flood control and 130,000 acre-feet for irrigation purposes. This is principally for supplemental supply for the Belle Fourche project in South Dakota.

Another Bureau project is the reconstruction and enlargement of the Eden project in northwestern Sweetwater County to eventually irrigate 20,200 acres of land and construction of the Big Sandy Reservoir on the Big Sandy River to a capacity of 39,700 acre-feet.

Construction is underway on the Flaming Gorge Dam on the Green River in Utah, which will back up water nearly to the city of Green River, Wyo. This is one of the units of the Upper Colorado River storage project, and among other benefits will provide power revenues for further Wyoming irrigation development and make possible great recreational development of the area.

Jackson Lake Dam and Reservoir on the Snake River about 25 miles north of Jackson, Wyo., was constructed by the Bureau of Reclamation under agreements with the Minidoka project in Idaho. The reservoir has a capacity of 847,000 acre-feet.

Several potential projects of the Bureau in Wyoming are the Seedskadee project, Lyman project, LaBarge project, Sublette project, Little Snake-Savery project, and Opal project in the Upper Colorado River Basin; the Shoshone extensions unit in the Big Horn River Basin; the Woodruff Narrows Reservoir on Bear River; the upper Star Valley project in Star Valley; the Sheridan Canal project on Tongue River; the Kaycee, Piney, French Creek, Buffalo, Ucross, and Crazy Woman units in the Powder River area.

Among the projects developed by the Federal agencies are the many ditches and some small reservoirs constructed by the U.S. Indian Service on the Wind River Indian Reservation.

Flood control in Wyoming

Flood damage in Wyoming has not been on such an extensive scale as in many other parts of the United States and irrigation reservoirs have fairly well controlled many of our streams. There have been many local floods caused by cloudbursts which are difficult to foresee or guard against.

Up to this time, what might be called direct flood control projects in Wyoming on any extensive scale have consisted principally of providing flood control storage capacity at Boysen, Glendo, and Keyhole Dams and the construction of levees and revetments along the Snake River near Wilson and the Big Horn River at Greybull with some work done on channel improvement of the Shoshone River near its mouth. Irrigation reservoirs have fairly well controlled the North Platte River and many of our other streams.

The 1944 Flood Control Act assigned to the Corps of Engineers, U.S. Army, the responsibility of prescribing regulations for the use of storage capacity allocated to flood control at reservoirs constructed wholly or in part with Federal funds. It further provided that the Corps should have the responsibility of determining flood control capacities in all reservoirs included in the comprehensive plan for the Missouri River Basin development. In addition, the Corps of Engineers is authorized by law to perform emergency operations and make flood control investigations.

Such emergency operations have been carried on along the Snake River in Jackson Hole in the vicinity of Wilson and to some extent at Greybull on the Big Horn River. Flood control works on the Snake River were authorized by the Flood Control Act of 1950. These will consist of revetted levees on about 18 miles of the river at a cost of about $2,700,000.

In addition to this, five local flood protective projects have been authorized for construction at locations that have suffered damaging floods in the past. These are at Greybull, on the Big Horn River, where severe ice jam floods and floodflows have occurred; on Clear Creek at Buffalo; on Big and Little Goose Creeks at Sheridan; at Dayton on Tongue River and Monarch on Tongue River.

Nonfederally constructed projects

The non-Federal developments consist of thousands of ditches, canals, pipelines, and small reservoirs, along practically all the streams in Wyoming. Some of the principal projects in this category are listed below:

Lakeview Canal	South fork, Shoshone River.
Cody Canal	Do.
Lovell Canal	Shoshone River.
Sidon Canal	Do.
Emblem Bench Canal	Greybull River.
Farmers Canal	Do.
Big Horn Canal	Big Horn River.
Upper Hanover Canal	Do.
Lower Hanover Canal	Do.
Bluff Canal	Do.
Kirby Canal	Do.
Cyclone ditch	Do.
Wyoming No. 2 Canal	Big Wind River.
LeClair-Riverton Canal	Do.
Big Goose and Beaver Canal	West fork, Big Goose Creek.
Peralta ditch	Little Goose Creek.
Colorado Colony ditch	Do.
Prairie Dog Water Supply Co. Canal.	North and South Piney Creeks.
Douglas Canal	North Platte River.
Lucerne Canal	Do.
North Platte Canal	Do.
Torrington Canal	Do.
Rock Ranch Canal	Do.
Hawk Springs Canal	Horse Creek.
Goshen Hole Canal	Do.
Goshen Canal	Do.
Wheatland Nos. 1 and 2 canals.	Laramie River and Sybille Creek.
Pioneer Canal	Laramie River.
Oasis Canal	Do.
Boughton Canal	Do.
Mesa irrigation canal	Savery Creek.
West Side Canal	Little Snake River.
First Mesa Canal	Do.
Bosler Canal	Rock Creek.
Canyon Canal	Do.
Table Land Canal	Medicine Bow River.
Haglund Canal	Do.
Paradise Canal	West fork, New Fork River.
Canyon Canal	Green River.
Boulder Canal	Boulder Creek.
Highland Canal	Willow Creek.
Apex Canal	Green River.
Jenkins Canal	West fork, New Fork River.
Bear Canal	Bear River.
Hilliard Canal	Do.
B. Q. canals	Do.
Coney Canal	Smiths Fork Creek.
Etna Canal	Salt River.
Wyoming Development Co. reservoir No. 2.	Laramie River.
Wyoming Development Co. reservoir No. 1.	Laramie River and Sybille Creek.
Lake Hattie Reservoir	Laramie River.
Hawk Springs Reservoir	Horse Creek.
Goshen Hole Reservoir	Do.
Goshen Reservoir	Do.
LaPrele Reservoir	LaPrele Creek.
Big Goose Park Reservoir	East fork, Big Goose Creek.
Big Horn Reservoir	Cross Creek.
Cloud Peak Reservoir	South fork, South Piney Creek.
Willow Park Reservoir	South fork, Piney Creek.
Twin Lakes No. 1 reservoir	West fork, Big Goose Creek.
Dome Lake Reservoir	Do.
Upper Sunshine Reservoir	Greybull River.
Pierce Reservoir	Rock Creek.
Shell Reservoir	Shell Creek.
Kearney Lake Reservoir	North fork, South Piney Creek.
Lake DeSmet Reservoir	Piney Creek.
New Fork Lake Reservoir	West fork, New Fork River.
Fremont Reservoir	Pine Creek.
Boulder Reservoir	Boulder Creek.
Sulphur Creek Reservoir	Sulphur Creek.
City of Cheyenne reservoirs	Crow Creek.

Wyoming has in recent years, under loans from the natural resource board, constructed a number of small reservoirs and canals to further our development and conserve water. Our State legislature has also authorized that board to contract for additional storage up to the amount of 60,000 acre-feet of water for municipal and industrial use in the Fontennelle Reservoir, a part of the Seedskadee project. This is under the authorization in Public Law 85-500.

To summarize our problems in connection with conservation of our water resources, they are as follows:

1. To supplement the water supplies for a considerable amount of our presently irrigated acreage by providing adequate storage.
2. To provide adequate water supply for future municipal and industrial uses in many parts of our State.
3. To fully develop our underground water potential.
4. To safeguard our future development by compacts with out neighboring States who share in the waters of our streams.
5. Adequate Federal legislation to safeguard and protect water rights secured under State laws in the West.

As we understand, the purpose of this committee is not to go into the question of Federal-State relations in the matter of water rights and water administration. It is, however, a question which we feel cannot be overlooked in a study of this kind. Each State has its own peculiar problems and in many fields is best qualified to work out those problems. We feel that adequate legislation by the Congress is necessary to safeguard the great development of our water resources that has been made under State laws and the water rights which have been acquired thereunder from encroachment by Federal departments and to offset certain Federal court decisions.

The potential for extensive industrial development in Wyoming because of our immense coal deposits and other minerals is very great and large quantities of water will be necessary for this purpose.

The potential of future development of irrigation is limited only by the available water supply, as we have tremendous acreages of irrigable land and development depends on costs as they may become feasible under future conditions. An estimate of potential development by 1980 would be an increase of 300,000 acres and by the year 2010, we think that 1 million acres over our present acreage will be irrigated.

Wyoming, through royalties on mineral lands, has been the greatest contributor to the Federal Reclamation Fund and our people must continue to urge that we receive benefits in water development to make up for those natural resources which have been used up in providing that contribution.

As a means of meeting future demands, I present the following observations:

(*a*) A very considerable part of new supplies can be added by conventional methods as land values increase to make feasible the costs of such developments.

(*b*) The control of water-consuming vegetation will help to conserve our water supply. In Wyoming, however, the willow and other growth along streams is valuable as shelter for livestock.

(*c*) Our experience in weather modification has not been very satisfactory to date. Wyoming, for several years, has had a weather modification board, consisting of the president of the State university, the commissioner of agriculture, and the State engineer.

(*d*) There are real possibilities in the reduction of reservoir evaporation by some type of cover and the reduction of seepage losses by different types of canal lining.

(*e*) Desalination of much of our water in arid areas would make a considerable amount of it usable for stock and domestic purposes and, in some cases, irrigation.

(*f*) Water use for pollution abatement has not been a serious problem in Wyoming as it has been in many Eastern States.

(*g*) New technical developments will assist in meeting future demands. These might provide cheaper power for pumping, prevention of evaporation losses, better recovery of underground waters, use of saline waters, and in many other ways.

PUERTO RICO

COMMONWEALTH OF PUERTO RICO,
OFFICE OF THE GOVERNOR,
La Fortaleza, San Juan, October 19, 1959.

Hon. Senator ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington.

MY DEAR SENATOR KERR: Pursuant to your request of June 23, 1959, I am pleased to enclose summary statement prepared by the Puerto Rico Water Resources Authority and the Puerto Rico Aqueduct and Sewer Authority on the water supply requirements of the Commonwealth of Puerto Rico during the coming years up to 1980, as well as some of the possibilities that are being considered to meet these needs.

As you will note, a broad and costly water resources development program will be required to provide an adequate supply to meet the domestic and industrial water needs during coming years.

Three agencies of the Commonwealth of Puerto Rico, the water resources authority, responsible for the development of water resources for electric energy and irrigation purposes, the aqueduct and sewer authority, responsible for the supply of water for domestic and commercial use, and the industrial development company, responsible for the development of the Commonwealth industrial program, entered in 1957 into a cooperative agreement with the U.S. Geological Survey to make a comprehensive investigation of the water resources of the island, both surface and underground water.

Any report in relation to this matter as well as any other information to be obtained from other studies and surveys will be forwarded to the Select Committee on National Water Resources as soon as available.

Cordially yours,

LUIS MUÑOZ MARÍN, *Governor.*

THE WATER SITUATION IN PUERTO RICO

GENERAL

Statistics of present water use and future demand for domestic, industrial, commercial, and agricultural use in the Commonwealth of Puerto Rico are anything but reassuring in the light of the available water sources capable of economic development.

The economy of the island rests basically on its agriculture and industry, which in turn depend greatly on the availability of a dependable and ample water supply.

Puerto Rico supports a population of 2,300,000 in an area of 3,420 square miles or 2,200,000 acres of land out of which only about 39 percent is suitable for agriculture, equivalent to one-third of an acre of agricultural land per capita as against 3 acres per person in the United States.

The gradual increase in the standard of living as a result of the Commonwealth government program for economic development is markedly increasing the per capita use of water.

Although rainfall in the island is abundant, its effective use is handicapped by the hilly topography which makes difficult and expensive the construction of storage reservoirs. The economical development and conservation of these waters is therefore a challenge to the responsible agencies.

SUMMARY OF WATER RESOURCES AVAILABLE

Rainfall

The island is in the path of the trade winds and is divided into two distinct zones by a mountain range that runs from east to west just south of its east-west axis. The mountain slopes on the south side are steep and there is a broad coastal plain from the foot of the range to the sea. Slopes on the north side are relatively gentle. About one-fourth of the area of the island has steep slopes and more than half lies 500 feet or more above sea level.

The moisture laden trade winds blowing from the northeast strike the northern side of the mountain range producing abundant rainfall on the northern slopes and scanty rainfall on the south side. Rainfall varies from 100 inches at the divide to 60 inches at the north seashore, and 30 inches at the south seashore. The extremes in rainfall range from about 200 inches in the Yunque Forest Reservation on the northeastern tip of the island to 30 inches or less along the extreme southwestern strip. The water year is divided into a wet and a dry season. The wet season starts in August and runs through November and the dry season is from December through July.

The average annual precipitation is 70 inches distributed as shown on exhibits 1 and 2 and equivalent to 13 million acre-feet of rainfall per year. Approximately 8 million acre-feet constitute the runoff into the streams discharging into the sea, and the balance of 5 million acre-feet evaporates or percolates into the underground reservoir. Exhibit No. 3 shows the approximate rainfall-runoff relation for Puerto Rico, and table No. 1 shows the determination of the average total yearly runoff. A large proportion of the runoff comes from rainfall in the coastal plains and cannot be stored.

Because of the topography of the island, the streams have a very short travel from the mountains to the sea, especially so on the south side, and are characterized by flash floods of relatively short duration. Large capacity reservoirs for the storage and conservation of the water falling during the rainy season c[illegible]nly be provided at prohibitive cost because [illegible] steep slopes of the streams and of the sides [illegible]he acute V valleys.

The dependable annual flow of the streams is estimated at 1,230,000 acre-feet of water. This estimate of dependable flow is based on the dry season flow and can only be increased by the regulation of the wet season flow of the streams. Storage reservoirs built to date for water supply, irrigation, and power with a storage capacity of 218,800 acre-feet provide partial regulation of streams with a total annual inflow of 975,000 acre-feet, as shown on tables Nos. 2 and 3. Possible sites for future development would increase the reservoir storage capacity by 320,000 acre-feet and would permit partial regulation of streams with about 1,600,000 acre-feet annual inflow, as shown on table No. 4.

Underground water

Underground water is being used for agricultural and domestic water supply. Fairly large aquifers have been identified in the tertiary limestone of the north coast and in the quaternary alluvium of the coastal plains and valleys of the north and south coasts.

The quantity and quality of the underground water potential is being investigated by the U.S. Geological Survey in cooperation with the Commonwealth government. Information obtained to date is not sufficient to estimate the amount of water available from the underground reservoirs; however, reliable information will be available as the present investigations progress.

STATEMENT OF WITHDRAWAL AND USE OF WATER

Domestic, commercial, and industrial water supply.—At present the total estimated population of Puerto Rico is 2,300,000 people. About 48 percent of it lives in urban areas and 52 percent in the rural zone. The total population is distributed among 76 municipalities, including the nearby islands of Vieques and Culebra. Except Culebra, all 75 cities and towns have water service 24 hours per day. Of the above population a total of about 1,630,000 people are at present served from public water supplies. Of these about 1,050,000 belong to the urban areas and 580,000 to the rural zone, which are mostly supplied from urban water supply systems.

Filtered water is served to 53 towns from 36 filter plants. Deep wells supply 17 other towns. Partially treated water is being served to the remaining five towns, but filter plants for all of them are now under construction or design and will be in operation in 1961.

Sanitary sewer systems exist in 63 towns; six more systems are under construction and six under design.

Water production by the Puerto Rico Aqueduct and Sewer Authority averages 90 million gallons per day and the normal trend shows an increase of about 5 percent per year.

Of the total daily production, 51 million gallons per day are consumed by the metropolitan zone of San Juan, which comprises 11 municipalities, and 39 million gallons per day by the rest of the island.

Of the total production of 90 million gallons per day, 6 percent is used by the authority for filter washing and other needs, and 25 percent of the balance constitute losses in transmission and distribution lines, etc.

The total number of customers as of June 30, 1959, amounted to 236,398, classified as follows:

Type	Number of customers	Water used	Water production
		Million gallons per day	*Million gallons per day*
Residential	209, 234	40. 0	57. 0
Commercial	22, 255	13. 5	19. 2
Industrial	1, 498	7. 5	10. 5
Public faucets	3, 411	2. 5	3. 3
Total	236, 398	63. 5	90. 0

In addition to the above, there are several private industrial establishments that utilize considerable amounts of surface and underground water taken directly from the streams and through pumping. There is little information available in connection with this use; however, most of these waters are returned to the streams.

Irrigation.—There are three Government irrigation districts in operation in Puerto Rico; the South Coast Irrigation District, the Isabela Irrigation District in the northwest corner of the island, and the recently constructed Lajas Valley Irrigation District (partially in operation). A large proportion of the waters utilized by the South Coast and the Lajas Valley Irrigation Districts come from the northern part of the island where they are stored and then conducted through tunnels for use in the dry south plains. These waters are used for producing hydroelectric energy before being released for irrigation.

The average total amount of water utilized by the three districts is of the order of 330,000 acre-feet. Table No. 2 shows statistical data on the existing reservoirs the waters of which are utilized for irrigation.

Besides the Government-owned irrigation districts there are many farms that are irrigated by pumping underground water. The exact amount of these waters is not known but from meager information available it is estimated that the same may be of the order of 250,000 acre-feet.

Some wells near the coast have been overpumped because of the increasing demand for water and have become contaminated with sea water. The quality of water from other wells may also deteriorate and the water levels may decline if provisions are not taken to control their operation.

Hydroelectric power.—The hydroelectric power potential of the island has been estimated to be of the order of 700 million kilowatt-hours per year. However, the economically feasible potential has proved to be substantially smaller.

To date, 300 million kilowatt-hours have been developed in 19 hydroelectric stations, ranging from 640 to 20,000 kilowatts in capacity. Table No. 5 shows statistical data on these stations including the estimated yearly inflows. It indicates that a total of 573,500 acre-feet of water per year is discharged at the tailrace of the hydro plants. Of this total, 193,000 acre-feet are delivered to the irrigation districts, 11,000 acre-feet are utilized for water supply, and 369,500 acre-feet are discharged into the streams that empty into the sea. Several sites remain, some of which have been studied in preliminary form, as shown in table No. 4, that do not appear to be justified for development for power generation and/or irrigation purposes alone. Table No. 4 lists the sites that have been studied in preliminary form. It shows the purpose of the development, the possible storage, the proposed hydroelectric capacity and the estimated cost of construction. The total cost of all these projects is of the order of $224 million.

The excessive cost of development of additional hydropower, as stated above, has occasioned a shift from hydro- to steam-electric generation during the last years, and the tremendous increase in the supply of electric energy to cope with the rapidly increasing industrialization of the Island will have to depend on thermal generation for years to come.

Some of the water-resources projects previously considered economically unfeasible will have to be reevaluated in the light of the pressing demand for water supply for domestic and industrial uses.

Fundamental problems.—As stated before, the progressive rise in the standard of living of the people has caused a corresponding increase in the per capita use of water. This coupled with the rapidly expanding industrialization of the island requires that the present water supply works be expanded and that new sources be developed.

The very low dry season flows of the streams preclude the construction of relatively low cost diversions and makes necessary the construction of storage works. Table No. 6 gives low season flows recorded in the spring of 1957 in streams near their outlets into the sea.

The unequal distribution of rainfall, abundant on the north and scanty on the south of the main divide, and the larger drainage areas on the northern slopes, result in relatively large runoff on the north streams and very low on the south streams. Many of the streams on the south side run dry during the dry season and the flow in the others is considerably reduced. Only during the rainy season is the flow of some of these streams of any value. In addition, there exists a problem of water rights in these southern streams. Water concessions have been granted adding in many cases up to more than the base flow of the streams. Some of these concessions were granted by the Spanish Crown and are irrevocable as a condition of the Treaty of Paris.

On the other hand, it is in the south coast where the best three natural harbors exist (Guánica, Guayanilla, and Jobos). These harbors have not been commercially developed and constitute potential sites for industrial complexes because of the maritime traffic facilities available. The lack of water is holding back the badly needed development of these harbors. The successful development of these facilities will probably require the storage and diversion of waters from north of the divide through the construction of dams and the driving of tunnels across the mountain range to transfer the waters to the south.

Exhibit 4 shows the location of the existing power, irrigation, and water supply reservoirs and the sites susceptible of future development. Table 4 lists these sites and the possible storage capacities that may be developed.

Reservoir silting.—The intensive cultivation of all lands, coupled with lack of reforestation, the use of clean till crops, and adverse effects of geology and topography, are responsible for the excessive soil erosion with resulting large amounts of sediment being transported and deposited in the existing reservoirs, significantly reducing their storage capacity each year. Out of the 18 storage reservoirs in operation serious silting has occurred in Guayabal and Coamo on the south side and Comerío on the north. In a period of about 45 years, Coamo and Comerío Reservoirs have practically lost their original storage capacity and Guayabal about 50 percent. The Guayabal Dam was raised 16 feet in 1951 in order to regain the storage capacity lost by siltation to that date.

The U.S. Soil Conservation Service is conducting special studies in the watersheds of Guayabal, Comerío, Caonillas, and Dos Bocas and is starting work in the Añasco River Basin for determining feasible procedures for erosion control. It is hoped that through the construction of erosion control works siltation of the reservoirs will be minimized.

Lack of proper control legislation.—At present there is inadequate legislation to guarantee the conservation of the surface and ground water resources through the adequate use of the water. There is no legislation for controlling the drilling and operation of wells except for minor restrictions as to location in respect to springs, rivers, canals, and other wells. No limitations are imposed on the quantities of water that can be pumped from wells. Steps will have to be taken to correct this situation.

Hydrologic data.—There are few reliable long-range hydrologic data of the streams not already developed. More information is necessary for conducting planning studies and designs. A cooperative program for the collection and evaluation of data on surface and underground water resources is being carried out since 1957 between the U.S. Geological Survey and the Commonwealth government. It is expected that this survey will furnish the required data for this planning.

Ground-water problem.—Deep wells have been a reliable source of water for irrigation and for domestic water supplies for many cities and towns of the island. As stated before the pressure for additional water to meet the increasing needs have caused the overpumping of some of the wells that eventually have become salty.

PROJECTIONS OF FUTURE DEMANDS FOR WATERS AND WATER RELATED ACTIVITIES

Population projections.—For the purpose of estimating future domestic and industrial water supply requirements, the population has been conservatively estimated at 3 million for the year 1980, equally distributed between the urban and rural areas. It is further estimated that out of this 3 million population, 2,300,000 can and will have to be served by public water supplies.

Municipal water use.—For residential and commercial use in urban areas an average future per capita consumption of about 80 gallons daily has been estimated against a present consumption of 60 gallons. Slum-clearance projects, more housing projects and higher living standards seem to justify the higher future rate of urban areas. For rural areas experience has shown that 30 gallons daily per capita is ample.

Basing future water demand on these rates the following figures are obtained for the year 1980.

Population to be served (for residential and commercial uses only)		Daily water rate	Total demand (million gallons daily)
Urban	1,500,000	80	120
Rural	800,000	30	24
Total	2,300,000	....	144

Agricultural use of water.—In addition to the lands now irrigated by the present three irrigation districts, there are about 25,000 acres scattered along the south and north coastal plains that are in need of irrigation for the support of year-round crops. Some of these irrigation systems were studied in preliminary form years ago. On the basis of present costs their development appears prohibitive.

Water needs for industry.—According to present projections, between the years 1960 and 1980 there will be established throughout the island about 2,000 new factories of which 10 percent will be heavy industries, 20 percent semiheavy, and 70 percent of the light type.

The total future industrial water need for 1980 has been estimated at 100 MGD of which the heavy industries will consume 60 percent, the semiheavy 10 percent, and the light industries 30 percent.

The net total future demand of water for domestic, commercial, and industrial purposes will, therefore, amount to 244 MGD which, increased by about 25 percent to account for losses, etc., becomes 305 MGD, or 215 MGD more than the present water production.

Electric energy.—The Puerto Rico Water Resources Authority is the government agency responsible for the supply of electric energy in Puerto Rico. The present installed capacity amounts to 388,700 kilowatts, of which 108,700 kilowatts is hydropower as shown in table No. 7.

In order to be able to provide the required energy for the rapidly expanding industrialization, the possible population increase, and the continuous increase in the use of electric appliances and facilities which follow the raising of the standard of living, it is necessary to periodically install additional steam electric generating units in the existing stations and perhaps to construct additional stations.

The yearly peak load increased from 55 megawatts in the year 1944, when the total installed capacity of the system was 71 megawatts, to 315 megawatts in 1959, or an increase of 260 megawatts in 15 years. Two steam electric and one gas electric units at present under construction will increase the installed capacity by 200 additional megawatts and will be in service by the middle of 1960. The present capacity (388.7 megawatts) is 547 percent of the capacity corresponding to the year 1944.

On the basis of present trends it is estimated that an average of about 50 megawatts capacity will have to be added every year. The fresh water requirements for this capacity are of the order of 75 gallons per minute or 121 acre feet per year, so that the total additional requirements for the year 1980 will be about 2 MGD. The above figures do not consider the large quantities of condenser circulating water required by the future units because sea water is utilized for this purpose.

The location and order of addition of the new units will depend on the results of load studies; however, there are only two stations where these additions would be installed, the Palo Seco Station near San Juan and the South Coast Station near Ponce.

MEANS OF MEETING FUTURE DEMAND

Possibility of adding new supplies.—The Puerto Rico Aqueduct and Sewer Authority has performed studies for determining the additional quantities of water that can be obtained from present or new sources and the approximate cost of the works required for catchment, purification, and transmission. These studies are outlined below and their results are summarized in table No. 8.

San Juan metropolitan area.—The water supply system of the metropolitan area, which at present serves about 550,000 people, produces about 50 MGD, of which 30 MGD are derived from the Loíza River and 20 MGD from the Bayamón and Guaynabo Rivers.

The estimated future demand for 1980 for a population of over 1 million for residential, commercial, and industrial uses amounts to 150 MGD. The future industrial demand alone has been estimated at 40 MGD.

In order to meet the future demand the following additional sources may be developed:

Source or river basin	Unregulated flow that may be used (MGD)	Estimated cost of the works
Loíza River [1]	30	$9,000,000
La Plata River [1]	15	4,000,000
Canovanillas River	3	1,000,000
Canóvanas River	5	2,000,000
Espíritu Santo and Grade Rivers	7	3,000,000
Mameyes River	10	5,000,000
Total	70	24,000,000

[1] Flow of these rivers is regulated by impounding dams.

The yield of Canóvanas, Espíritu Santo, Grande, and Mameyes Rivers may be further increased from 22 MGD to about 35 MGD by regulating their flows through impounding dams, at a combined estimated cost of $10 million.

In addition to these developments, the effluent from the metropolitan sewage treatment plant, which may amount in the future to 30 MGD or more, may be recovered and treated for industrial use, at an estimated cost of $9 million.

In accordance with the above, the metropolitan zone of San Juan may be supplied an additional flow of about 110 MGD over the present supply at an estimated cost of $43 million.

Ponce City.—Ponce is the second largest city in Puerto Rico. Its urban population in 1950 was around 100,000 and the estimate for 1980 is about 160,000. The future rural population which may be served from the city system is estimated at 25,000. The estimated future water demand is as shown in the following table.

Population to be served		Use	Daily rate (gallons per capita)	Total demand (MGD)
Urban	160,000	Residential and commercial	75	12.00
Rural	25,000	do	30	.75
		Industrial		14.00
Total	185,000			26.75

At present the city of Ponce is supplied from the tailrace waters of Garzas hydroelectric plant No. 2 and from Portugues River. Five deep wells are kept in reserve. There are two filter plants; an old one of 4 MGD capacity, and a new one of 5 MGD, which can be enlarged to 10 MGD at an estimated cost of $1,200,000.

The present sources of water are as follows:

	MGD
(*a*) Garzas aqueduct	12
(*b*) Portugues River (dry season flow)	1
(*c*) Five deep wells	4
Total	17

Additional sources which may be developed are the Portugues and Toa Vaca Rivers through the construction of dams to impound 4 MGD, and 6 MGD, respectively. Thus, 10 MGD may be added to the water supply system of Ponce, at an estimated cost of $12 million to complete a total supply of 27 MGD required by 1980.

Mayaguez City.—Mayaguez is the third important city in the island. Its urban population in 1950 was 59,000. It is estimated that for 1980 this population will be about 86,000. Of its future rural population, about 20,000 will be supplied from the city aqueduct. The estimated future water demand is as follows:

Population to be served		Use	Daily rate (gallons per capita)	Total demand (MGD)
Urban	86,000	Residential and commercial	75	6.45
Rural	20,000	do	30	.60
		Industrial		10.00
Total	106,000			17.05

At present the city of Mayaguez is supplied from Cañas and Yaguez Rivers. The system has two filter plants, an old one of 3 MGD capacity, and a new one of 5 MGD under partial operation. The combined minimum flow of both rivers is 4 MGD, but construction will begin this year of an intake structure and pumping station at Añasco River, to supply the new filter plant, completing its total capacity of 5 MGD. Añasco River is one of the largest in the island, so that the future water demand of Mayaguez can be supplied by pumping from the river. Besides a gravity system may be completed from Cañas River, by the construction of an impounding dam to regulate its flow to yield from 6 to 8 MGD at a cost of around $2 million.

Caguas City.—The 1950 population of Caguas was about 34,000 and the estimate for 1980 is 50,000. Its water supply system also serves the town of Gurabo, with a future estimated population of 7,000. The rural residents that may be served in the future are about 18,000 for Caguas, and 6,000 for Gurabo. The future industrial demand is estimated at 2 MGD. The following table shows the future demand:

Population to be served		Use	Daily rate (gallons per capita)	Total demand (MGD)
Urban	57,000	Residential and commercial	70	3.99
Rural	24,000	do	30	.72
		Industrial		2.00
Total	81,000			6.71

At present the city of Caguas is supplied from Quebradillas Creek with a minimum flow of 2 MGD which matches the present filter plant capacity of 2 MGD. Construction is underway to increase the capacity of the plant to 4.75 MGD. The additional supply required will be obtained from Turabo River, for which works are also under construction.

In the future waters from the Loiza River will be used to supply 2 MGD additional at an estimated cost of $1 million.

Other smaller towns.—The following table shows the estimates of future demand for 15 other towns.

Towns	Capacity of present waterworks (million gallons per day)	Estimated 1980 population		Future demand (million gallons per day)			River source, additional demand	Cost estimate, million dollars
		Urban	Rural	Domestic	Industrial	Total		
Arecibo	2.5	50,000	20,000	4.10	4.00	8.10	Tanama	2.3
Aguadilla, Aguada, and Moca	3.0	50,200	42,000	4.77	1.88	6.65	Irrigation canal, Humacao	1.2
Humacao and Las Piedras	1.0	25,000	20,000	2.35	1.34	3.69	Mariana Creek	1.3
Fajardo and Ceiba	1.6	27,000	12,000	2.25	2.40	4.65	Fajardo	1.4
Guayama and Arroyo	1.5	39,000	16,000	3.21	3.70	6.91	Chiquito	3.0
Luquillo	.5	3,000	6,000	.36	.50	.86	Sabana	.1
Quebradillas	.2	3,300	10,000	.50	.10	.60	Guajataca	.35
San Germán and Lajas	1.0	18,500	29,000	1.98	.52	2.50	Rosario	1.0
Vieques Island	.15	5,000	5,000	.40	.10	.50	Blanco	1.6
Totals for 15 towns	11.45	221,000	160,000	19.92	14.54	34.46		12.25

Special industrial zones.—The Puerto Rico Industrial Development Co. is planning the installation of several petrochemical industries near the present Commonwealth Oil Refinery at Tallaboa, near the towns of Guayanilla and Peñuelas. The future water requirements for this zone, including the town of Guánica, have been estimated at 45 million gallons per day.

The first 10 million gallons per day may be supplied from the main canal of the Lajas Valley Irrigation District at an estimated cost of $5 million.

Other possible future sources of water are the Rosario and Guanajibo Rivers, both on the western side of the island. Rosario River may be impounded to obtain a regulated flow of 30 million gallons per day, which may be increased by utilizing the Duey, Hoconuco, Ohio, and Gupeyes Rivers, tributaries of the Guanajibo River up to 40 million gallons per day, at an estimated cost of $32 million. The main Guanajibo River could also be utilized in the future and may yield about 34 million gallons per day.

Towns of the central, south, and southwest zones of Puerto Rico.—The small towns along the central, south, and southwest zones are mostly supplied from deep wells, but generally the yield of these wells is small. Until a report on the findings of the water resources survey being conducted by the U.S. Geological Survey is submitted, no estimates of the underground waters which may be obtained for the use of these towns will be available.

Towns along the central highlands.—Most of the towns located along the central highlands are small and the capacity of their water supply systems is just enough for their domestic and commercial uses.

Other cities and small towns along the west, north, and northeast coasts.—Prospects for these towns are favorable. Their future demands can be supplied from the rivers on those zones.

Water supply systems being improved.—The water supply systems of the towns of San Sebastián, San Lorenzo, Vega Baja, Adjuntas, and Peñuelas are being improved and will have facilities to supply the future demands. The improved waterworks for these five towns will have a combined capacity of 3.60 million gallons per day.

The water resources authority is responsible for the supply of electric energy and operation of the irrigation districts, the aqueduct and sewer authority is responsible for the supply of water for domestic and commercial uses, and the Industrial Development Co. is responsible for the development of the industrialization program of the Commonwealth of Puerto Rico. These agencies are, therefore, definitely concerned with the availability of water and with the satisfactory solution of the water problems. For this reason it was considered appropriate to secure the aid of the U.S. Geological Survey to make an appraisal of the surface and underground water resources of the island. A cooperative agreement was therefore signed with the U.S. Geological Survey, whereby the Geological Survey will perform the necessary investigations which include the determination of the quality of the water. This agreement is in effect since July of 1957 and the field work is being started at present. Information obtained from the results of this program will serve to complement this summary statement.

TABLE 1.—*Total yearly runoff in Puerto Rico*

Rainfall (inches)	Area		Rainfall (acre-feet)	Approximate runoff factor	Runoff (acre-feet)
	Square mile	Acres			
30	130.0	83,200	208,000	0.30	62,400
40	257.5	164,800	548,784	.40	219,514
50	195.0	124,800	520,416	.48	249,800
60	396.0	253,440	1,267,200	.55	696,960
70	922.5	590,400	[illegible],147,936	.60	2,068,762
80	765.0	489,600	3,265,632	.64	2,090,004
90	452.5	289,600	2,172,000	.68	1,476,960
100	178.5	114,240	951,619	.70	666,133
110	54.0	34,560	316,915	.73	231,438
120	27.5	17,600	176,000	.74	130,240
130	17.5	11,200	121,296	.76	92,185
140	11.5	7,360	85,891	.77	66,136
150	6.0	3,840	48,000	.78	37,440
160	1.0	640	8,531	.79	6,739
170	2.5	1,600	22,672	.79	17,911
180	.5	320	4,800	.79	3,792
190	1.0	640	10,131	.80	8,105
Total	3,418.5	2,187,840	13,175,823		8,124,429

TABLE 2.—*Dams of Puerto Rico*

Name of dam	Location		Year completed	Type	Structural height, foundation to crest (feet)	Length of crest at crest elevation (feet)	Volume content of dam (cubic yards)	Reservoir name	Reservoir capacity (acre-feet)	Purpose	Installed power capacity (kilowatts)
	River	Nearest city									
Adjuntas	Adjuntas	Adjuntas	1950	Gravity.	80	230	15,000	Adjuntas	465	Irrigation	(1)
Antonio Lucchetti.	Yauco	Yauco	1952	do	178	591	102,000	Antonio Lucchetti.	16,500	Power and irrigation.	8,000
Caonillas	Caonillas	Utuado	1948	do	235	815	230,000	Caonillas	49,000	Power	17,600
Carite	Carite	Guayama	1913	Earth	104	530	200,000	Carite	11,300	Power and irrigation.	4,640
Comerio No. 2	La Plata	Comerio	1913	Buttress.	128	480	40,000	Comerio	600	Power	5,240
Dos Bocas	Rio Grande de Arecibo	Arecibo	1942	Gravity	188	1,317	301,400	Dos Bocas	32,000	do	18,000
Garzas	Vaca	Adjuntas	1943	Earth	202	910	1,031,000	Garzas	4,700	Power and irrigation.	12,240
Guajataca	Guajataca	Guajataca	1924	do	110	900	520,000	Guajataca	32,600	do	3,200
Guayabal	Jacaguas	Juana Diaz	1913	Buttress.	120	920	44,000	Guayabal	10.000	Irrigation	
Guayo	Guayo	Adjuntas	1956	Gravity.	190	555	121,000	Guayo	17,400	Power and irrigation.	20,000
Guineo	Toro Negro	Villalba	1931	Rockfill.	125	565	319,300	Guineo	1,800	do	1,920
Loco	Loco	Yauco	1953	Gravity.	72	600	19,300	Loco	1,950	Irrigation	
Rio Grande de Loiza (Loiza).	Rio Grande	Caguas	1951	do	100	700	67,000	Rio Grande de Loiza.	20,000	Water supply and power.	2,600
Matrullas	Matrullas	Villalba	1934	Earth	120	710	496,000	Matrullas	3,000	Power	8,640
Patillas	Patillas	Patillas	1913	do	147	1,020	920,000	Patillas	14,500	Irrigation	
Pellejas	Pellejas	Adjuntas	1950	Gravity.	50	195	4,600	Pellejas	152	Power	(1)
Prieto	Prieto	do	1955	do	98	260	12,200	Prieto	730	Power and irrigation.	(2)
Vivi	Vivi	do	1950	do	85	238	13,800	Vivi	277	Power	4,000
Yahuecas	Yahuecas	do	1956	do	90	450	18,400	Yahuecas	1,800	Power and irrigation.	(2)

[1] Adjuntas and Pellejas Reservoirs' waters are diverted to Vivi Reservoir for power production.

[2] The Yahuecas, Guayo, and Prieto Reservoirs are interconnected.

TABLE 3.—*Storage capacity of existing reservoirs showing average yearly inflows*

[In acre-feet]

Reservoir	Irrigation only		Irrigation and power		Power only		Power and water supply	
	Storage capacity	Average yearly inflow	Storage capacity	Average yearly inflow	Storage capacity	Average yearly inflow	Storage capacity	Average yearly inflow
Patillas	14,500	60,700						
Carite			11,300	30,000				
Coamo [1]	0	23,300						
Guayabal [2]	10,000	80,400						
Garzas							4,700	21,000
Dos Bocas					32,000	279,500		
Rio Blanco [3]					8	40,000		
Comerio					600	173,500		
Caonillas [4]					49,000	[4] 123,500		
Southwestern P. R. project [5]			38,350	120,000				
Guajataca			32,600	70,000				
Loiza River							20,000	150,000
Total	24,500	164,400	82,250	220,000	81,608	493,000	24,700	171,000

[1] Reservoir completely silted in.

[2] Water from Matrullas and Guineo Reservoirs are discharged into the Guayabal Reservoir by way of the Jacaguas River.

[3] Run of the River Plant.

[4] Caonillas Reservoir inflow of 123,500 acre-feet is included in Dos Bocas inflow. The tailrace waters of the Caonillas hydroelectric plant discharge into Dos Bocas Reservoir.

[5] This project comprises the reservoirs of Guayo, Yahuecas, Prieto, Lucchetti, and Loco.

TABLE 4.—*Hydroelectric projects studied in preliminary form*

Name of dam	Location		Reservoir capacity (acre-feet)	Available water (acre-feet)	Estimated generating capacity (kilowatts)	Approximate cost [1]
	River	Nearest city				
Rosario	Rosario	San Germán	3,400	35,700	([2])	$43,500,000
Guanajibo	Guanajibo	do	4,500	17,500	([2])	
Saliente	Saliente	Jayuya	None	2,000	6,300	3,305,000
Jayuya	Jayuya	do	16,000	76,500	2,500	8,600,000
Jauca	Jauca	do	1,900	4,400	3,400	3,500,000
Toa Vaca	Toa Vaca	Villalba	11,800	15,000	([2])	11,422,000
Coamo-Bauta	Coamo-Toa Vaca Bauta.	Coamo	4,286	38,200	4,800	13,368,000
Orocovis	Orocovis	Orocovis	1,400	55,000	4,000	5,827,000
Rio Blanco extension	Hicaco	Naguabo	3,200	32,600	9,000	5,779.000
Comerio extension	La Plata	Comerio	36,800	128,500	22,000	16,037,000
Matacañas	Matacañas	Morovis	36,400	129,000	9,000	11,907.000
Sana Muertos	Sana Muertos	Orocovis	2,000	7,000	1,760	2,684,000
Manatí	Manatí	Ciales	144,300	240,000	25,000	21,859,000
Cialitós	Cialitos	Jayuya	None	9,000	1,900	1,370,000
Dos Bocas extension	Arecibo	Arecibo	1,250	280.000	9 000	9,374,000
Tanamá	Tanama	Utuado	6,200	33,300	6,400	9,420.000
Añasco	Añasco	Las Marías	31,000	415,600	18,800	28,691,000
El Verde	Espiritu Santo	Canóvanas	1,700	16,600	2,800	18,168,000
Tres Saltos	Canóvanas	do	[illegible]	16,000	1,400	
Guzmán Arriba	Grande	Río Grande	1.600	11,700	900	
Baño de Oro	Mameyes	Luquillo	1,300	17,000	1,000	
Cubuy	Canóvanas	Canóvanas	6,300	52,100	3,500	9,270,000
Total			318,150	1,632,700	133,460	224,081,000

[1] Original project costs adjusted in accordance with present cost indexes.

[2] No power.

Table 5.—*Hydroelectric plants' water discharged at the tailrace*

Plant	Installed capacity (kilowatts)	Reservoir capacity (acre-feet)	Water discharged [1] at the tailrace (acre-feet)
Comerio Nos. 1 and 2	4,800	600	90,000
Carite Nos. 1, 2, and 3	4,640	11,300	17,000
Isabela Nos. 1, 2, 3, and 4	3,840	32,600	55,000
Toro Negro Nos. 1 and 2	10,560	4,860	21,000
Garzas Nos. 1 and 2	12,240	4,700	19,000
Dos Bocas	18,000	32,000	[2] 250,000
Caonillas No. 1	17,600	49,000	
Caonillas No. 2	4,000	1,442	
Yauco No. 1	20,000	19,000	
Yauco No. 2	8,000	16,500	[3] 100,000
Rio Blanco	5,000	8	21,500
Total	108,680	17,202	573,500

[1] Discharges shown correspond to inflows less spillings.
[2] Includes the waters of Caonillas plants Nos. 1 and 2.
[3] Includes the waters of Yauco plant No. 1.

Table 6.—*Dry season flow of streams near their outlets to the sea—data for spring of 1957*

Stream	Point of gaging	Flow (cubic feet per second)	Remarks
Río Grande de Loíza.	Road No. 3 at Carolina	36.67	Regulated by Puerto Rico Aqueduct and Sewer Authority.
Canovanillas	Road No. 3, near Canóvanas.	2.79	
Canóvanas	Road No. 3, kilometer 18.1	4.85	
Herrera	Road No. 3, kilometer 21.5	1.83	
Río Grande	Road No. 3, kilometer 25.2	21.51	
Espíritu Santo	Road No. 3, kilometer 25.9	7.03	
Mameyes	Road No. 3, kilometer 32, at Palmer.	16.84	
Sabana	Outside of Luquillo	6.18	
Pitahaya	Road No. 3, kilometer 42.5, at Hacienda Margarita.	2.46	
Fajardo	Road No. 3, kilometer 50.2	11.75	
Daguao	Road No. 3, kilometer 63.4	.56	
Quebrada Esperanza.	Road No. 3, kilometer 65.1	1.12	
Ancón	Road No. 3, kilometer 71.8	5.00	Discharge estimated—river mouths closed by sandbars.
Río Blanco	Road No. 3, kilometer 72.2	10.00	
Antón Ruiz	Road No. 3, kilometer 73.9	5.00	
Humacao	Road No. 3, kilometer 85.2	9.05	
Qubrada Cataño	Road No. 3, kilometer 87.4	.34	
Quebrada Grande.	Road No. 3, kilometer 94.0	.37	
Ingenio	Road No. 3, kilometer 94.7	2.41	
Guayanés	Road No. 3, kilometer 98.4	28.91	
Caño Santiago	Road No. 3, kilometer 99.0	.09	
Maunabo	Road No. 3, kilometer 110.2.	12.69	
Merle	Road No. 3, kilometer 120	.49	
Jacaboa	Bridge, Road No. 3	([1])	
Chico	Road No. 3, kilometer 125.9.	([1])	
Patillas	Road No. 3, kilometer 128.6.	2.39	Downstream from the dam.
Arroyo	Road No. 3, kilometer 135.0.	.19	

Table 6.—*Dry season flow of streams near their outlets to the sea—data for spring of 1957*—Continued

Stream	Point of gaging	Flow (cubic feet per second)	Remarks
Guamaní	Road No. 3, kilometer 146.6	([1])	
Salinas	Road No. 3, outside of Salinas.	([1])	
Jueyes	Road No. 1	([1])	
Coamo	Road No. 1	([1])	
Descalabrado	Road No. 1 at Central Cortada.	.20	
Cañas	Road No. 1	([1])	
Jacaguas	Road No. 1	([1])	
Inabón	Road No. 1	([1])	
Bucaná	Road No. 1	([1])	
Portugués	Road No. 1, at Ponce	([1])	
Magueyes	Road No. 2	([1])	
Tallaboa	Road No. 2, at bridge	3.00	
Guayanilla	Road No. 2, Yauco-Guayanilla section, bridge at crossing outside of Peñuelas.	1.50	Stream was dry at Guayanilla.
Yauco	Road No. 2, at Yauco	0	Discharge controlled by Lucchetti and Loco.
Loco	Road No. 2	0	Reservoirs of the S.W.P.R. project and by water rights.
Guanajibo	Road No. 2, kilometer 216.2, at Sabana Grande.	([1])	Discharges estimated—Flow at kilometer 192.8 includes the discharge of Rosario River. The figure shown includes the flows of 2 and 4 cubic feet per second at kilometer 209.2 and 198.9.
	Road No. 2, kilometer 209.2, outside of San Germán.	2.00	
	Road No. 2, kilometer 198.9.	4.00	
	Road No. 2, kilometer 192.8.	12.00	
Quebrada Sábalos.	Road No. 2, kilometer 188.3.	.50	
Yagüez	At Mayagüez	2.00	Flow regulated by aqueduct and sewer authority.
Añasco	At Igualdad Sugar Mill	80.00	Discharge estimated.
Culebrinas	At Coloso Sugar Mill	43.50	
Guajataca	At the mouth	20.39	
Camuy	At Riollano Sugar Mill	63.23	
Arecibo	At Cambalache Sugar Mill.	80.00	Discharge regulated by Dos Bacos Reservoir.
Manatí	Road No. 2, kilometer 53.5	112.44	
Cibuco	Old Road No. 2 near Carmen Sugar Mill.	25.92	
La Plata	Road No. 2, kilometer 23.1, at Dorado Crossing.	65.96	
Bayamón	At Palo Seco	5.00	Two outlets to sea obstructed by sandbars. River headwaters regulated by aqueduct and sewer authority.
Total discharge of all streams.		[2]706,16	

[1] Dry.
[2] Total discharge of 706.16 cubic feet per second equivalent to 456.4 million gallons per day.

TABLE 7.—*Capacity of existing thermo and hydroelectric stations*

Station	Installed capacity (kilowatts)	Capacity available for peaking	
		May 1 to Nov. 30 (kilowatts)	Dec. 1 to Apr. 30 (kilowatts)
Thermoelectric stations:			
Santurce	15,000	12,000	12,000
Mayaguez (steam)	5,000	5,000	5,000
Mayaguez (gas) (No. 1)	20,000	20,000	20,000
San Juan	160,000	188,000	188,000
South Coast (units 1 and 2)	80,000	100,000	100,000
Total steam and gas electric capacity	280,000	325,000	325,000
Hydroelectric stations:			
Carite	4,640	2,500	2,500
Toro Negro 1	8,640	8,640	8,000
Toro Negro 2	1,920	1,920	1,500
Garzas 1	7,200	7,200	7,000
Garzas 2	5,040	5,000	5,000
Comerio	4,800	4,800	2,000
Rio Blanco	5,000	5,000	3,000
Dos Bocas	18,000	15,000	15,000
Caonillas 1	17,600	17,600	16,000
Caonillas 2	4,000	4,000	----------
Yauco 1	20,000	24,000	24,000
Isabela 1 to 4	3,840	2,000	2,000
Yauco 2	8,000	10,000	10,000
Total hydroelectric capacity	108,680	107,660	96,000
Total thermo and hydroelectric capacity	388,680	432,660	421,000

TABLE 8.—*Summary of present and future water demand for domestic, commercial and industrial uses*

Municipality or zone	Present capacity (million gallons per day)	Additional future demand (million gallons per day)	Preliminary cost estimate of providing additional supply
San Juan metropolitan zone covering 11 municipalities	51	110	$43,000,000
Ponce City	17	10	12,000,000
Mayaguez City	6	11	5,000,000
Caguas City	5	2	1,000,000
15 additional cities and towns	11	23	12,250,000
Special industrial zone of Guayanilla and Guanica	7	50	37,000,000
Total (for 31 cities and towns)	97	206	110,250,000

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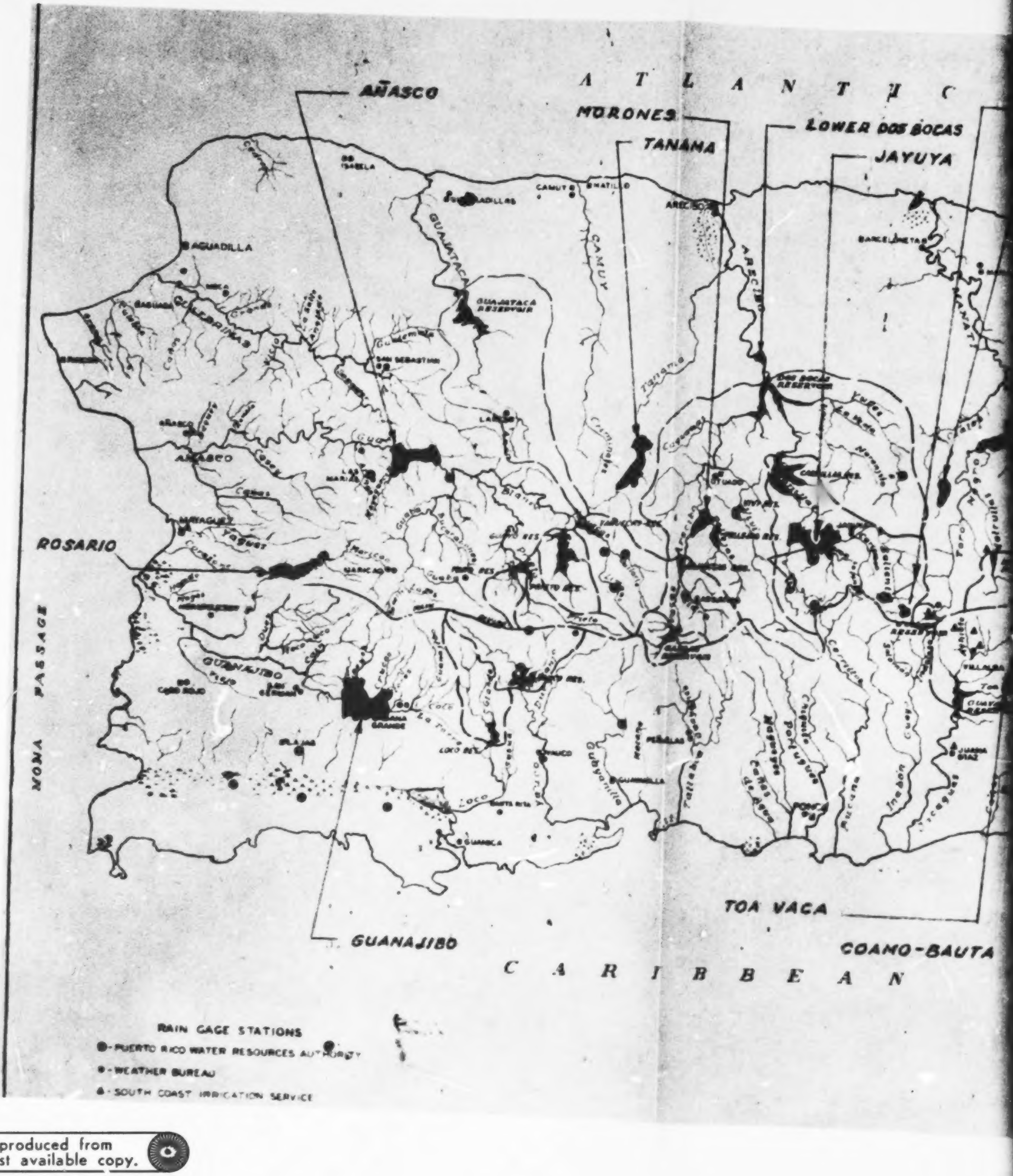
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CARIBBEAN
MONA PASSAGE
AGUADILLA
GUAJATACA RESERVOIR
CAMUY
ARECIBO
TANAMA
DOS BOCAS RESERVOIR
CULEBRINAS
MAYAGUEZ
GUANAJIBO
YAGUEZ
BARCELONETA
RAIN GAGE STATIONS
● - PUERTO RICO WATER RESOURCES AUTHORITY
● - WEATHER BUREAU
▲ - SOUTH COAST IRRIGATION SERVICE

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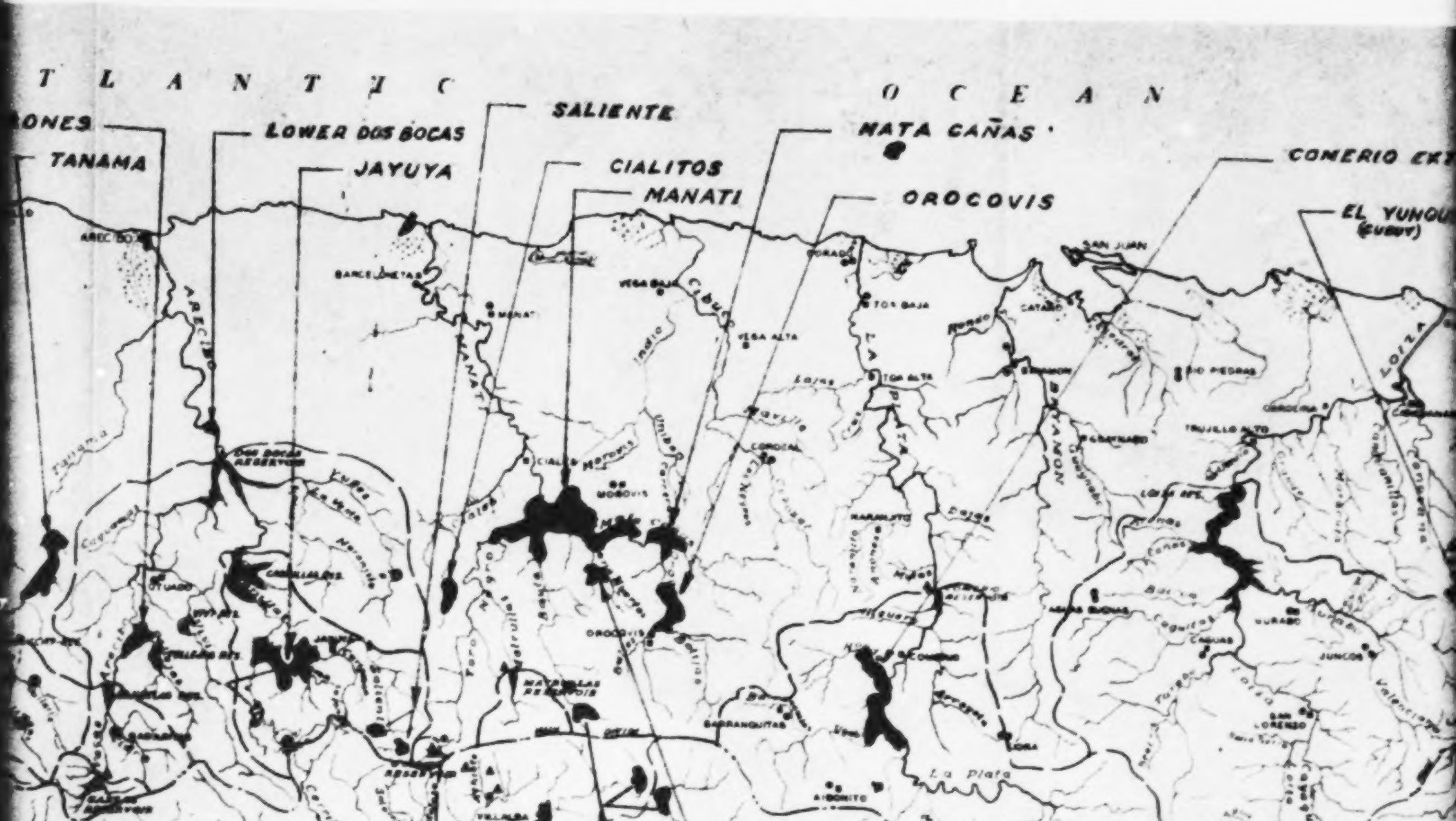
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(CUBUY)
ARECIBO
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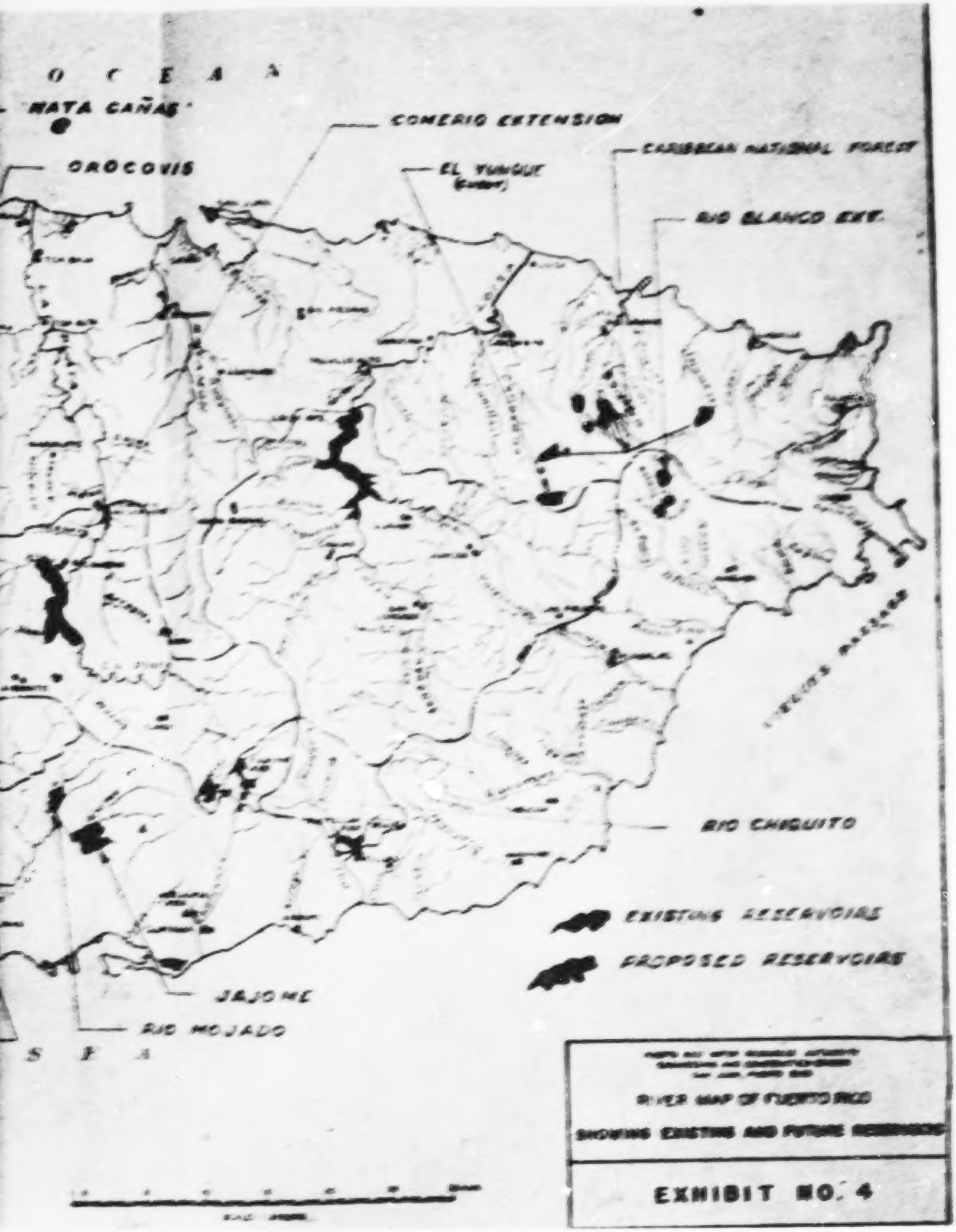
EXHIBIT NO. 4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RIO CHIQUITO
EXISTING RESERVOIRS
PROPOSED RESERVOIRS
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RIO MOJADO
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SHOWING EXISTING AND FUTURE RESERVOIRS
EXHIBIT NO. 4

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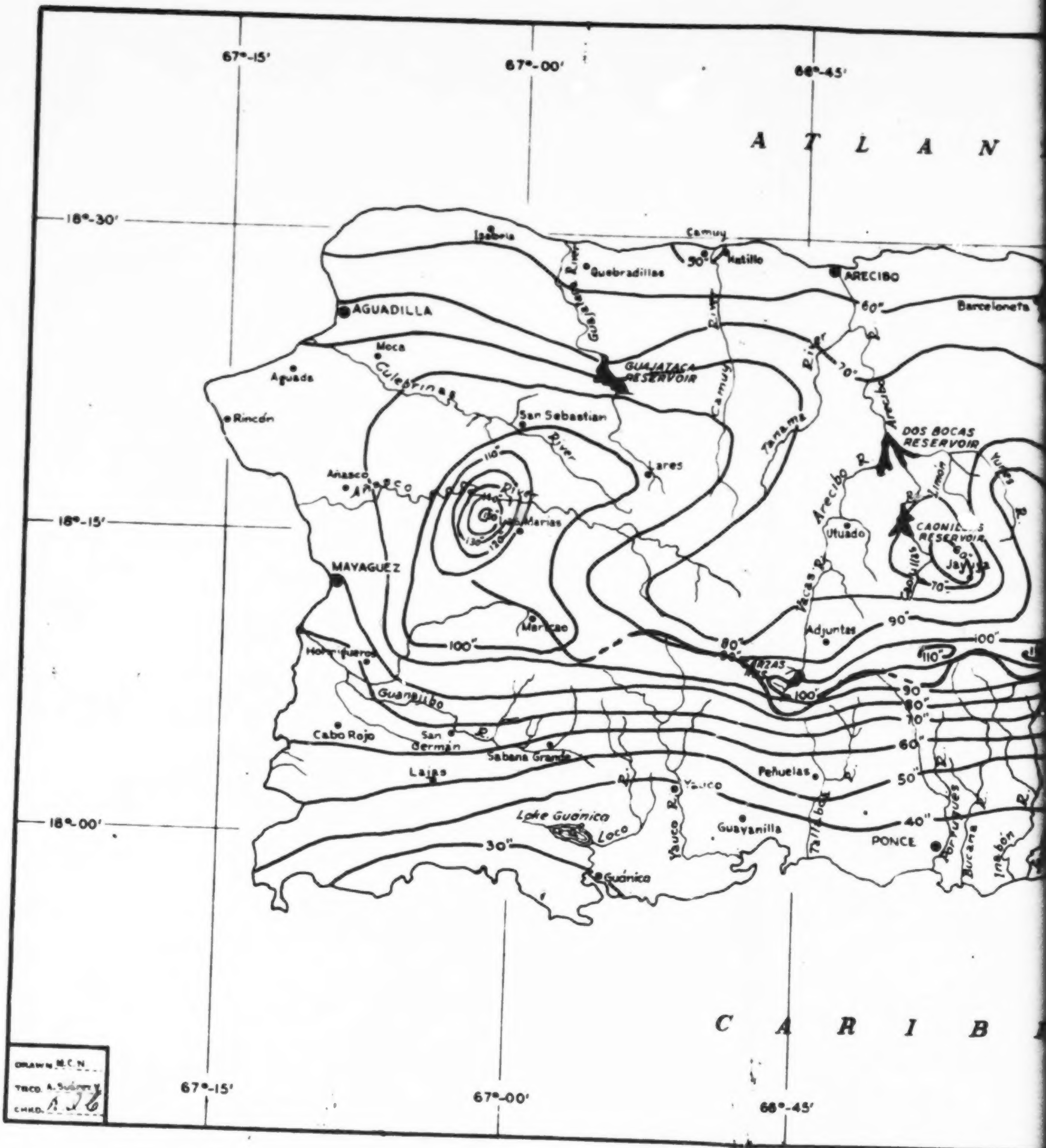
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Rincón
Culebrinas
GUAJATACA RESERVOIR
San Sebastian
Lares
DOS BOCAS RESERVOIR
CAONILLAS RESERVOIR
Añasco
Añasco River
Las Marias
Utuado
Jayuya
MAYAGUEZ
Maricao
Adjuntas
Hormigueros
Guanajibo R.
Cabo Rojo
San Germán
Sabana Grande
Lajas
Yauco
Peñuelas
Lake Guánica
Loco
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Camuy R.
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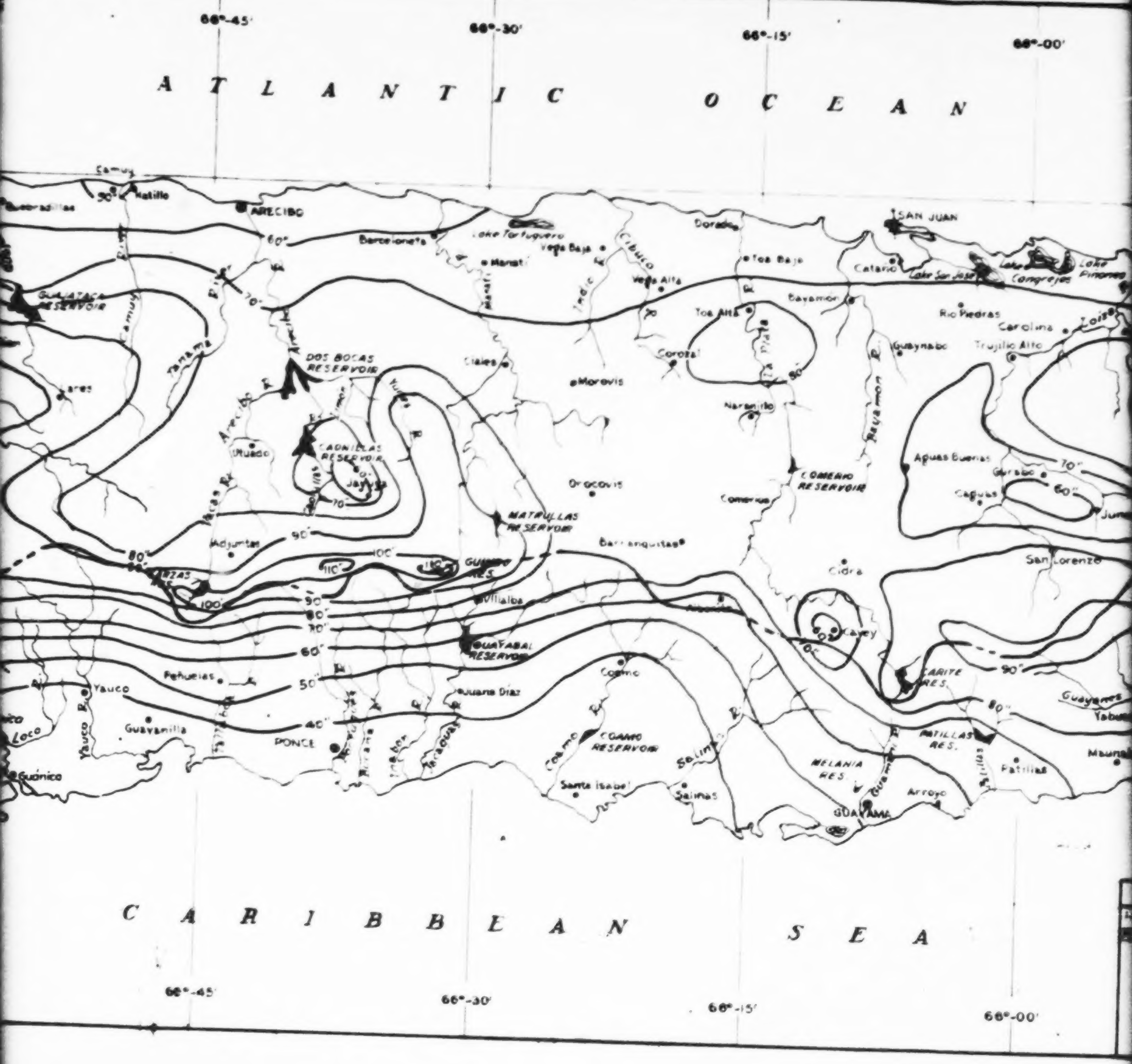
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Manati
Dorado
SAN JUAN
Toa Baja
Cataño
Lake San José
Lake Congrejos
Lake Piñones
Vega Alta
Toa Alta
Bayamon
Rio Piedras
Carolina
Loiza
Guaynabo
Trujillo Alto
GUAJATACA RESERVOIR
Camuy R.
Tanama R.
Arecibo R.
Cibuco
Indio R.
La Plata
Bayamon R.
DOS BOCAS RESERVOIR
Lares
Ciales
Morovis
Corozal
Naranjito
Utuado
CAONILLAS RESERVOIR
Jayuya
Orocovis
COMERIO RESERVOIR
Comerio
Aguas Buenas
Gurabo
Caguas
Juncos
MATRULLAS RESERVOIR
Barranquitas
Adjuntas
YAHUECAS RES.
GUINEO RES.
Villalba
Aibonito
Cidra
Cayey
San Lorenzo
GUAYABAL RESERVOIR
CARITE RES.
Guayama
Yabucoa
Peñuelas
Yauco
Yauco R.
Guayanilla
Guanica
Juana Diaz
Coamo
Coamo R.
COAMO RESERVOIR
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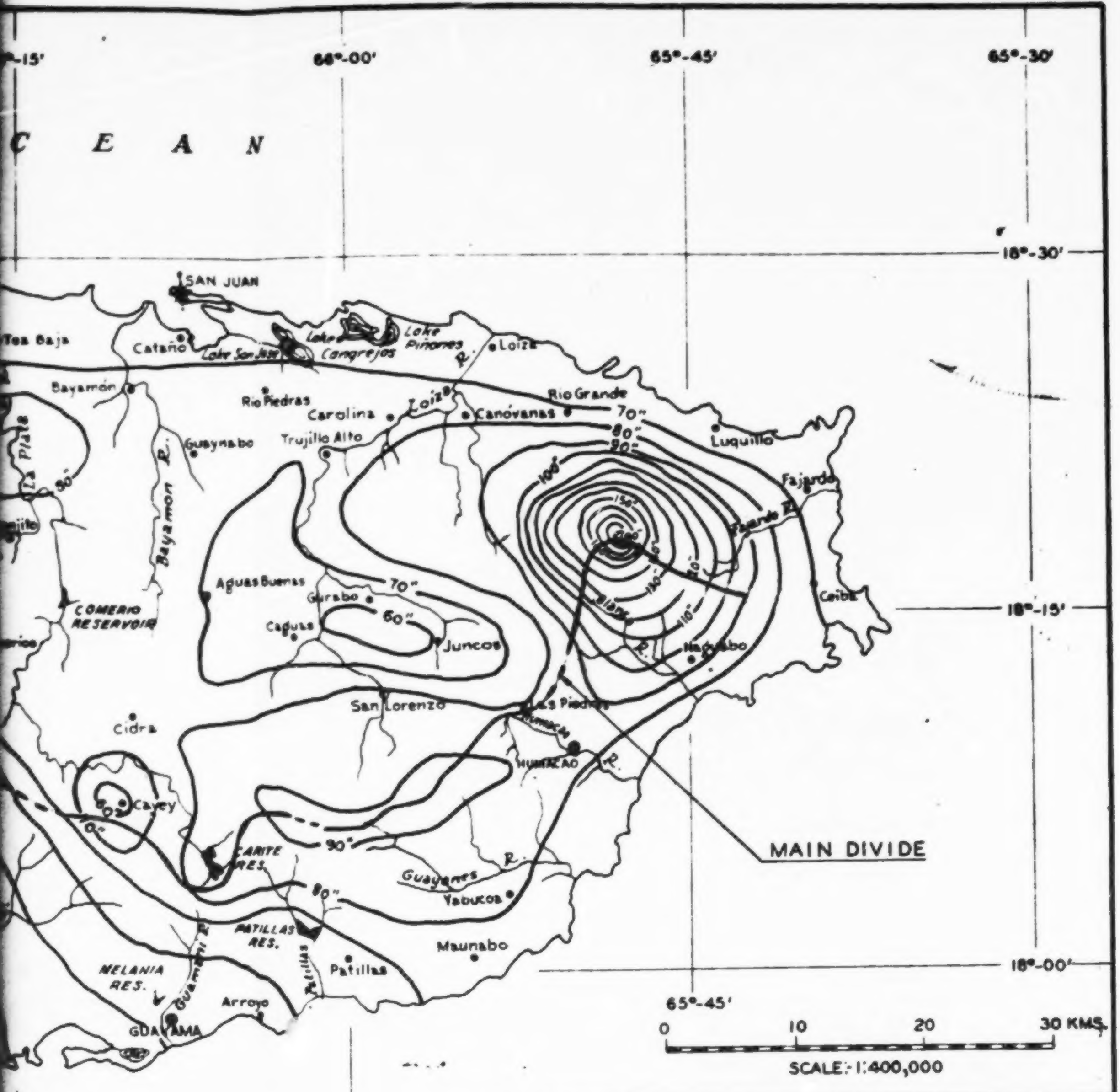
EXHIBIT NO. 1



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Bayamón
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Carolina
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Canóvanas
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La Plata
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Guaynabo
Trujillo Alto
Bayamon R.
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Fajardo
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REVISIONS

1. REVISED TO 1952

XI-30-52 RM. Jr.

PUERTO RICO WATER RESOURCES AUTHORITY
ENGINEERING AND CONSTRUCTION DIVISION

MAP OF PUERTO RICO
SHOWING DISTRIBUTION OF RAINFALL

SUBMITTED | RECOMMENDED | APPROVED

SCALE: NOTED. | SAN JUAN, P. R. | JULY, 1952

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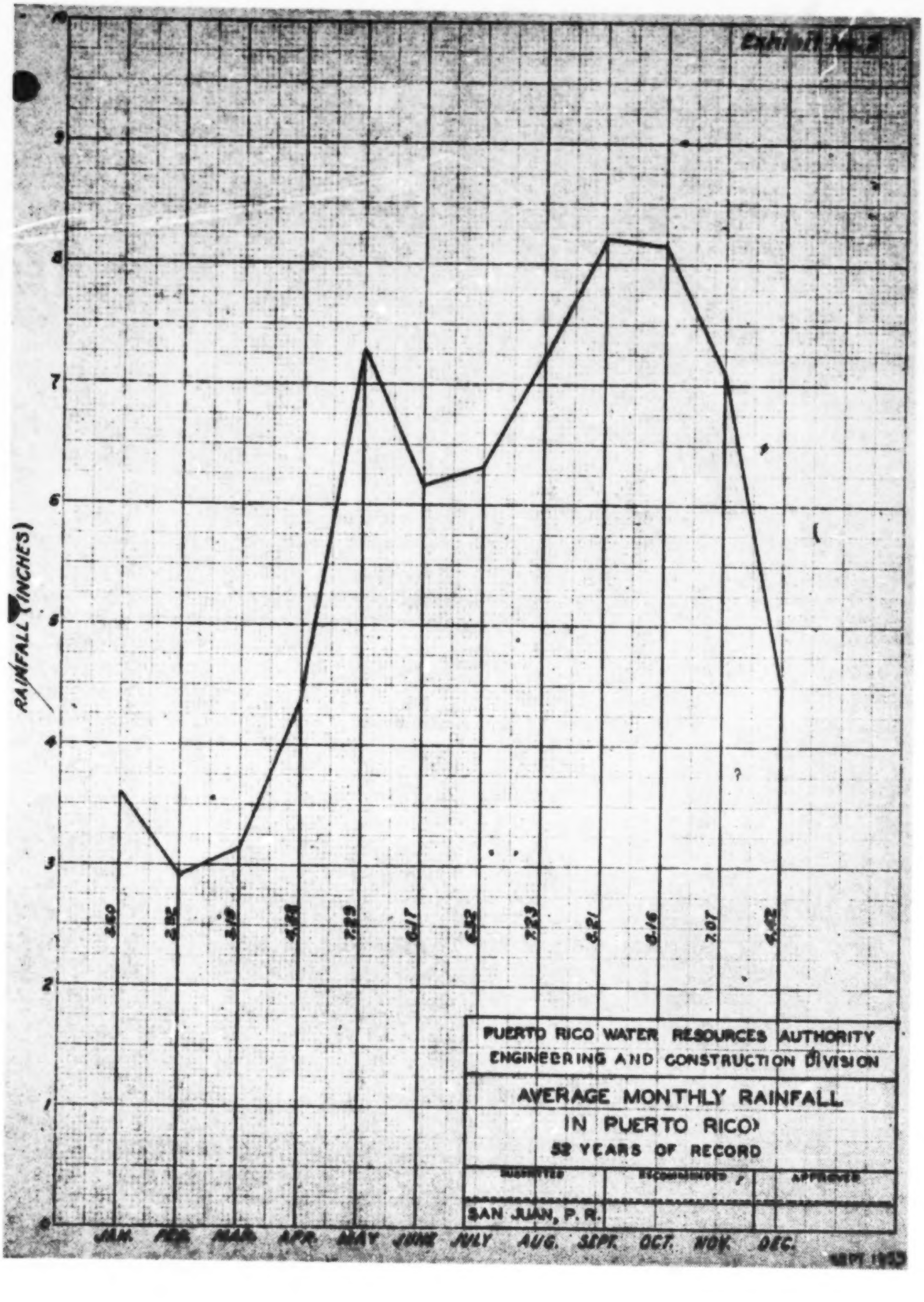
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MAR.
APR.
MAY
JUNE
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AUG.
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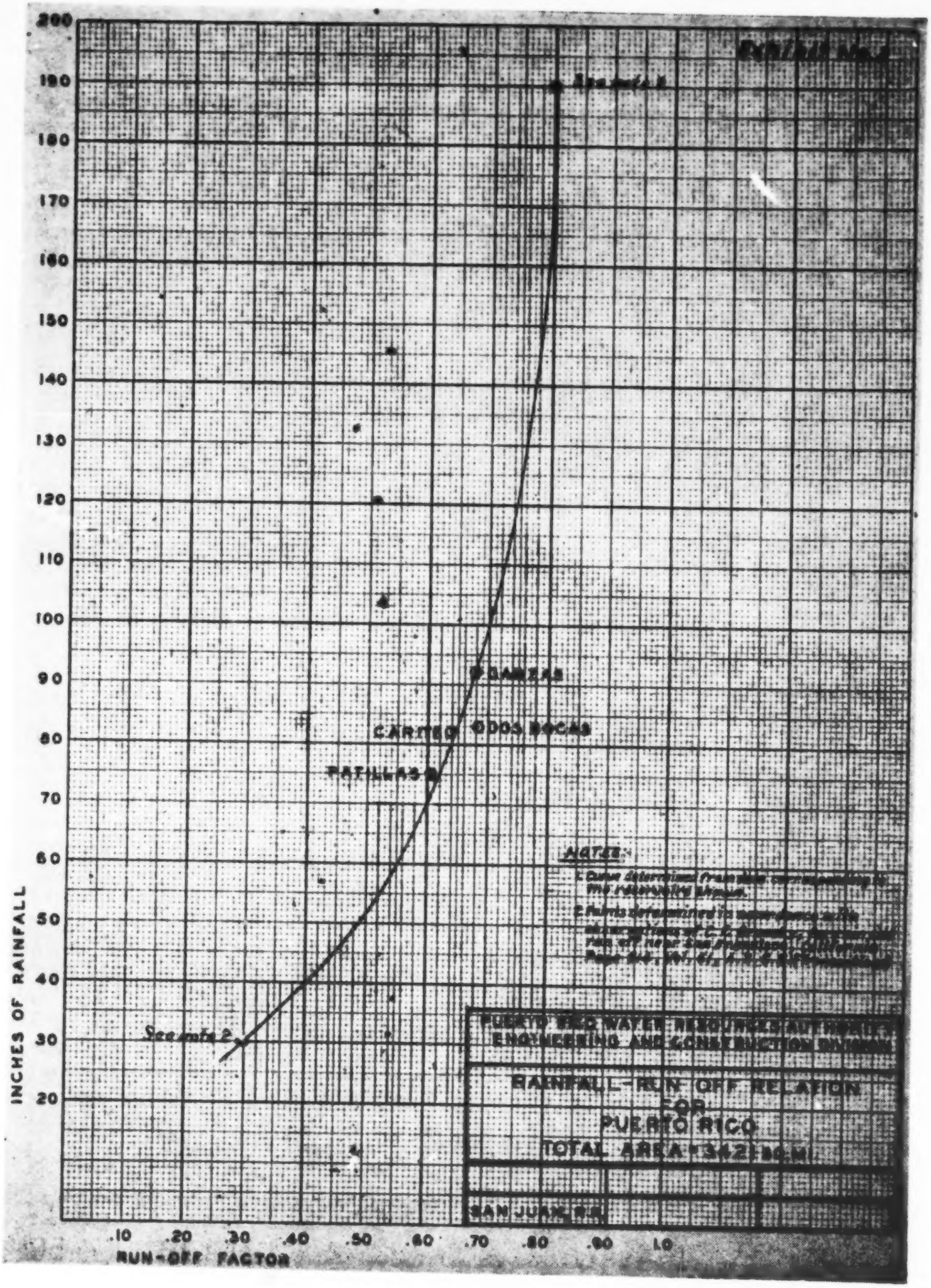
NOV.
DEC.
PUERTO RICO WATER RESOURCES AUTHORITY
ENGINEERING AND CONSTRUCTION DIVISION
AVERAGE MONTHLY RAINFALL
IN PUERTO RICO
52 YEARS OF RECORD
SUBMITTED
RECOMMENDED
APPROVED
SAN JUAN, P. R.


See note 2
CARITE
PATILLAS
GARZAS
DOS BOCAS
See note 2
NOTES:
1. Curve determined from data corresponding to the reservoirs shown.
2. Points determined in accordance with the
PUERTO RICO WATER RESOURCES AUTHORITY
ENGINEERING AND CONSTRUCTION DIVISION
RAINFALL-RUN OFF RELATION
FOR
PUERTO RICO
TOTAL AREA = 3421 SQ.MI.
SAN JUAN, P.R.
INCHES OF RAINFALL
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.0
RUN-OFF FACTOR

TERRITORIES AND ISLAND POSSESSIONS

U.S. Department of the Interior,
Office of the Secretary,
Washington, D.C., January 20, 1960.

Hon. Robert S. Kerr,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

Dear Senator Kerr: We are pleased to submit to the Senate Select Committee on National Water Resources 20 copies of the report on "Water Resources of Guam, American Samoa, Trust Territory of the Pacific Islands, and the Virgin Islands." This report was requested by you on November 16, 1959.

Sincerely yours,

Elmer F. Bennett,
Acting Secretary of the Interior.

Water Resources of the Island of Guam

The island of Guam is the most westerly territory of the United States and is the southernmost and largest of a chain of 17 volcanic islands known as the Mariana Islands. Shaped like a kidney bean, it is 32 miles long, and 4 to 8½ miles wide, covering an area of 225 square miles.

The civilian population (39,333) obtains water supplies from several sources. The island is unique in that the central and northern portion is a broad terraced limestone plateau with high cliffs to the ocean, and the only water source is from the fresh-water lens formed by the rainfall penetrating and filtering through the porous rock formation. A note of interest—one of the reports on water shows that more than 85 percent of the rainfall in the northern and central part of the island, due to the porous limestone formation, penetrates to form the fresh-water lens. There are no rivers or streams in this portion of the island, there being very little runoff.

The average annual rainfall, from figures available, is 86.7 inches. The springs in the northern part have their discharge just a few feet above the high-tide level. At times sea water mixes with the fresh water and causes the water to be brackish. There are no springs being used in this area for the civilian population water supply.

At the present time the only withdrawal of ground water by the public utility agency for civilian use is to serve the village of Yigo (population 953), with 10.2 million gallons per year. The village of Dededo (population 2,323), and surrounding area is served from water produced by the Air Force from ground water installations which amounted to approximately 42.8 million gallons for the year 1958, and for a corresponding period in 1959 is 47.3 million gallons. Information is not publicly available as to the total amount of ground water withdrawn by the military installations.

The terrain in southern Guam for the most part is hilly and the underlying rock has moderate to low permeability; therefore, a large part of the rainfall is discharged quickly by surface runoff. The streams respond rapidly to rainfall and subside almost immediately, after the rain stops. Storm runoff rapidly flowing over the highly weathered volcanic rock carries considerable amounts of silt.

The streams in Guam are short, the valleys, especially inland, are narrow and steep sided. As the shore is neared, the gradient becomes more gentle and the valleys widen and terminate in small bays. Since the gradients near the shore are gentle, tidewater migrates upstream during high tide. The majority of the streams originate in the weathered upland volcanics, which discharge sufficient water through seepage and small springs to maintain dry weather flow for the perennial streams. (See attached "average discharge" figures.)

The Public Utility Agency of Guam has developed some of these rivers and springs to serve the civilian population with safe, clean, potable water.

Location	Population (June 30, 1959)	Million gallons per year (1958)
Umatac	651	8.3
Merizo	1,333	20.3
Inarajan	1,716	21.8
Asan	1,493	60.1

The Ylig River Plant served the villages of Yona, Talofofo, Camp Witek, and Camp Dealey areas with 133.7 million gallons for the year 1958. The rest of the villages were served with 960.3 million gallons purchased from the Navy's Fena System. All the above figures are for the civilian population only and do not include the military.

The civilian per capita consumption has increased in the past few years due to the plant extensions to make water available to these areas. Houses being modernized and new washing machines are the greatest causes of the per capita increase.

In fiscal year 1959 the public utility agency installed 53,453 linear feet (over 10 miles) of larger water mains and 71 additional fire hydrants. The number of water customers has increased from 6,708 on June 30, 1958, to 7,011 on June 30, 1959, an increase of 4.5 percent. Likewise, the daily consumption has jumped from 2,240,598 gallons per day to 2,306,056 gallons, an increase of 3 percent.

Sewage disposal is one problem that should be given a great deal of consideration very soon. Agana Spring, one of the largest, is not being used due to the pollution from seepage from septic tanks in a nearby village. Sewers should be installed and the sewage carried to the ocean for disposal so as to preserve the ground-water supply.

To meet the future water demands of the civilian population will not be a great problem, even with increased per capita consumption. The temporary water mains that were installed by the military are being replaced with permanent mains. Each new main decreases water leakage so the original supply serves more people. The public utility agency has made a projected 5-year plan for developments and extensions, and within the next 3 years most of the old mains will be replaced and the leakage reduced. The probability of any great amount of water for industrial use in the foreseeable future is small, and the same is true for any great amount for agricultural development due to the limited amount of good soil and area available. As for the climate, even during the dry season the records show that there is, on the average, over an inch of rain per month, and thus, with the humidity factor of 70 to 90 percent during the dry season, not a great deal of water is required.

The future demands for water will require the outlay of substantial capital to build storage and filtration plants on the existing rivers to preserve the present water that is now running back to the ocean.

The greatest problem at the present time is the lack of transmission and distribution mains to all the areas. They are only fed from a certain source and there is the lack of cross connections to maintain service at all times. The projected future plans are to install permanent lines of adequate capacity to have water available from more than one installation.

Average discharge

River	Average discharge [1]		Million gallons a day
	Period of record (fiscal years)	Cubic feet per second	
1. Talofofo River, near Talofofo	1952–58	50.2	32.4
2. Almagosa Springs, near Agat	1952–58	3.51	2.27
3. Tolaeyuus River, near Agat	1952–58	22.0	14.2
4. Ugum River, near Talofofo	1952–58	28.0	18.1
5. Ylig River, near Yona	1952–58	23.0	14.9
6. Pago River, near Ordot	1952–58	22.6	14.6
7. Lonfit River, near Ordot	1952–58	10.6	6.85
8. Pauliluc River, near Inarajan	1953–58	5.40	3.49
9. Inarajan River, near Inarajan	1953–58	16.1	10.4
10. Umatac River, at Umatac	1953–58	7.34	4.74
11. La Sa Fua, near Umatac	1953–58	4.43	2.86
12. Geus River, near Merizo	1953–58	2.95	1.91
Total			127

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[1] From open file report, Surface-Water Supply of Guam, Mariana Islands, 1951–58, U.S. Geological Survey.

Water sources contributing to the Government (bay area) water system with distribution mains from Utulei Village on the south to Leloaloa Village on the north consist of: Collection of surface runoff water from approximately 200 inches of rainfall per year into two concrete gravity-type dams; one concrete catchment basin without storage facilities; and a well located in Pago Pago Valley at the head of the Pago Pago Bay.

(*a*) The Faga'alu (upper) Reservoir is located near the head of the Faga'alu Valley base of Mount Matafao, approximately 2 miles from the station. The entire reservoir together with a portion of the watershed is U.S. Government property. The capacity of the reservoir is 1,720,000 gallons and the top of the concrete dam is approximately 812 feet above sea level. It is an open concrete gravity-type dam and subject to landslides during periods of heavy rainfall. The dam intercepts surface runoff from the watershed in the general locality of Matafao Peak and water discharged from a series of springs with an estimated yield of 394,000 gallons daily. Water from this reservoir is directed to the Fagatogo (lower) Reservoir through 4,700 feet of 12- and 10-inch cast iron pipes to the ridge above the Fagatogo Reservoir at 674 feet above sea level and branched into two 6-inch cast iron pipes for 2,000 feet discharging into the Fagatogo Reservoir.

(*b*) The Fagatogo (lower) Reservoir is of the same type and construction as the Faga'alu, damming the Fagatogo Gorge with the dam top at 190 feet above sea level with a capacity of 445,000 gallons. A concrete diversion channel follows one side of this reservoir making it possible either to use or to bypass the water from the Fagatogo Valley watershed area. Water from this reservoir is distributed into the water mains through an 8 by 6 by 8-inch venturi meter, through three 155 gallons per minute Permutit type E horizontal filters with sand gravel filtering media operated in parallel through the chlorinator plant at 130 feet above sea level where chlorine gas is injected into the water by two M-5 chemichlorinators.

(*c*) The Pago Pago catchment basin located at the head of the Vaipito Creek at 460 feet above sea level is a concrete constructed dam without storage facilities collecting surface runoff. Water from the catchment basin through mesh strainers is diverted into a return line into the Fagatogo Reservoir through 4,500 feet of 8-inch cast iron pipe. The return line of 7,000 feet of 8-inch cast iron and steel pipe and 6-inch cast iron pipe with a booster pumping station was originally designed to serve as a booster station from Pago Pago well to the Fagatogo Reservoir. Both the Fagatogo Reservoir and the Pago Pago catchment basin collect water from springs or seepages in small quantities. During August 1956, the period of lowest yield, a spring at the Fagatogo Reservoir yielded an estimated 30,000 gallons daily and the estimated yield of the Pago Pago catchment from springs and seepages was 125,000 gallons per day.

(*d*) Ground water from one dug well, Pago Pago well, was completed in 1943. The shaft is 74 feet deep, with a system of horizontal infiltration tunnels totaling 325 feet with an estimated yield of 90,000 gallons per day. This property near Pago Pago Village is 58 feet above sea level. It is capped with a small wood frame building that houses two 25-horsepower vertical shaft deep well turbine pumps. The well is connected to the old ship repair facility by 9,000 feet of 10-inch cast iron pipe. A concrete water tank of 60,000 gallons capacity provides storage during the off-pumping periods. Water is further distributed to Leloaloa through 4,155 feet of 6-inch black steel pipe and 3-inch galvanized pipe. Other distribution mains not mentioned above include 3,000 feet of 8-inch and 5,640 feet of 6-inch cast iron mains and 1,500 feet of 4-inch galvanized branch mains.

Roughly four-fifths of the sources of water for the Samoan communities outside of the bay area consists of reservoirs or pools in surface streams. The most common developments are small reservoirs formed by masonry or concrete dams across small streams. Some of these reservoirs have capacities of several thousand gallons which are distributed to the villages by means of galvanized pipe. In the villages, the outlets in the pipelines consist of ¾-inch pipe risers 7 to 8 feet high bent to direct the stream downward into shallow concrete basins. To these outlets people of the villages come for water for drinking and cooking and to bathe and wash clothes. No water is used for sewage disposal except in dispensaries.

All reservoirs are subject to filling by silt and flood debris and the water in most has high turbidity. Because of farming on the mountain slopes and the presence of foraging pigs all surface water sources are subject to pollution in the watershed areas. There is further danger of pollution by human and animal agents in the reservoir themselves, none of which is protected. With a few exceptions each village has its own water supply and the maintenance of the system and regulation of use are responsibilities of the people of the village.

The present consumption of water from the Government (bay area) water system is 970,000 gallons per day. Major use of the Government water supply is to meet the increasing demand for human consumption and uses related thereto, such as for sanitary and domestic purposes and industrial use. Only a small amount of the supply is utilized as boiler feed water and as cooling water for the powerplants. Although there is ample rainfall, rainless periods of from 5 to 7 weeks occur and water supplies often become critically short.

The projected future demand for municipal and industrial use is 3 million gallons per day.

In order to solve water problems and meet the increase demand on the water supply, the Government of American Samoa and the Geological Survey under a cooperative agreement have installed six stream gaging and rain gaging stations at selected streams and sites on the island of Tutuila to collect basic data relative to the hydrology and geology of the island and to obtain information that can be used in planning improvements in the water supplies of the island. The Government of American Samoa with the cooperation of the Geological Survey, Surface Water Branch, has measured 65 ungaged streams. This program will continue for the next 4 years. The basis for selecting these ungaged sites is to provide answers to the following questions:

1. What are the minimum and average discharges of the principal streams near every village on Tutuila?
2. Should the administrative area of Pago Pago or the airport require the development of additional surface water supplies, at what altitude on what stream can a known increase be developed with a minimum expenditure for pipes, filters, etc.?
3. What is the rainfall runoff ratio in various parts of the island? This yields valuable clues in estimating ground water storage and recharge.

Metering of flat-rate consumers is being considered as a way of eliminating wastage.

The water problem of Tutuila in its essence is the problem of supplying safe water regularly and in sufficient quantity for the development of the health, welfare, and the economy of the territory. The island's average rainfall of 200 inches is ample, but it is during the periods of dry spells the water shortage is sadly experienced.

Considerable improvement can be made in the health program as the sanitation standards of the island are still primitive. Increasing demands being made by industry and shipping must be adequately met to provide for industrial needs. The increase in shipping and the development of the airfield at Tafuna, the influx of tourists and the development of hotels require additional water storage and distribution to utilities. The future economy and welfare of this island therefore hinge upon the full development of improved water supply to meet all requirements by continuing our cooperative agreement with the Geological Survey, Surface and Ground-Water Branch.

Water Resources of the Trust Territory of the Pacific Islands

As the Trust Territory of the Pacific Islands does not have water systems as such, except in the various district headquarters (several of which do not have meters), the following report is for the most part a general one:

1. *Water resources available*

(*a*) *Rainfall.*—The following is the average rainfall by districts for a 5-year period covering the years 1954 through 1958.

District:	Yearly average in inches
Rota	88.0
Yap	121.4
Koror	149.2
Truk	149.4
Ponape	200.0
Marshalls	139.6

(*b*) *Ground water.*—Due to the topography and the very porous coral and limestone formation of the various islands, the amount of ground water is very limited. In certain areas, shallow dip wells are used. However, in most areas rainwater from roofs is caught in drums or concrete catchments.

2. Present withdrawal and use

(*a*) *Domestic use by districts.*—

Rota: 26,000 gallons per day, estimated.

Yap: 3,500 gallons per day, estimated.

Koror: 200,000 gallons per day, part metered and part estimated.

Truk: 67,675 gallons per day, part metered and part estimated.

Ponape: 223,350 gallons per day, part metered and part estimated.

Marshalls: 20,000 gallons per day, estimated.

The estimated native per capita daily consumption in villages and outlying islands is 10 to 50 gallons per day for each of approximately 68,000 inhabitants or a maximum of 3,400,000 gallons per day.

(*b*) *Industrial use.*—The only water used in the trust territory that could be considered for industrial use is that used for cooling water in the district powerplants' wash racks in the district repair shops and water furnished to ships in the various districts. Water furnished to the district ships averages approximately 3,500 gallons per day. The amount used for all other industrial use is estimated to be 5,000 gallons per day.

(*c*) The only agricultural usage at the present time would be that used in the district's agricultural stations. There are no irrigation systems in the trust territory at the present time.

3. Projection of future demand

This problem is now under study. There will no doubt be increases in all categories; however, it would be impossible to make an estimate at this time.

4. Means of meeting future demands

The only means of meeting any future demands would be by additional storage, pumping stations, and expansion of present district waterlines. Technical asistance to the various villages and outlying islands is given by the public works and sanitation departments on a cooperative basis.

5. Problems and possible solutions

No major problems in supplying any future reasonable demands are foreseen other than financing. This will by necessity have to be carried out over a period of several years.

WATER RESOURCES OF THE VIRGIN ISLANDS

The American Virgin Islands, comprising more than 50 islands, lie approximately 40 miles east of Puerto Rico. Only three, St. Thomas, St. Croix, and St. John, have any size or population. The total area of the three is less than 140 square miles. Most of the remainder are uninhabited. In 1955 the population of St. John was estimated at 794, St. Thomas at 15,453, and St. Croix at 13,369.

The islands are mountainous and are of volcanic origin. They have a warm, sunny climate with an average annual rainfall of 45 inches. However, there is a marked seasonal unbalance between wet and dry portions of the year. Ground water is extremely limited and primary reliance has been placed upon a series of catchments for the storage of rainwater.

St. Thomas, the most populous island, also has the most serious water shortage. For some years the local water supply has been supplemented by barging and in fiscal year 1958 a total of 39,104,400 gallons was so supplied at a cost of approximately $5 per thousand gallons, excluding the costs of distribution.

The increasing population of St. Thomas and the growing tourist industry have made the solution of the water shortage more urgent. Following studies of alternative possible solutions, it has been concluded that the desalinization of sea water is the most economical and practical method of meeting the needs of St. Thomas. Attached is a copy of a statement submitted on July 6, 1959, to the Committee on Interior and Insular Affairs, U.S. Senate, which summarizes the water needs of St. Thomas and outlines the several possible methods of meeting the demand, including sea water distillation.

U.S. Department of the Interior,
Office of the Secretary,
Washington, D.C., July 6, 1959.

Hon. James E. Murray,
Chairman, Committee on Interior and Insular Affairs,
U.S. Senate, Washington, D.C.

Dear Senator Murray: Enclosed herewith is a copy of my statement concerning sources of potable water for St. Thomas, V.I. The statement is submitted pursuant to section 3 of Public Law 85–913, which authorizes the Virgin Islands Corporation to construct, operate, and maintain salt water distillation facilities in St. Thomas, subject to certain stated conditions. The construction of such facilities is conditioned upon, among other things, a conclusion by the Secretary of the Interior "that such facilities will most economically and expeditiously provide an adequate supplemental supply of potable water for St. Thomas."

Public Law 85–913 also requires the submission to your committee of the principal contract for the construction of the facilities, together with an explanatory statement of the Secretary's conclusion, the reasons therefor, and supplemental data concerning alternative sources of water which have been investigated.

The enclosed statement indicates that, on the basis of all of the information currently available, I have concluded that salt water conversion facilities will provide the most economical and expeditious supplemental supply of potable water. The statement summarizes the reliability and cost of the principal alternative sources of water; i.e., barge supply, pipeline, ground water, watershed areas, and catchment areas.

When engineering and economic studies, currently underway, are completed, we shall submit a further statement concerning the particular method of salt water conversion which we have selected as most suitable for meeting the needs of St. Thomas. At that time we shall also submit the principal construction contract to your committee.

Sincerely yours,

(Signed) Fred A. Seaton,
Secretary of the Interior.

Statement by the Secretary of the Interior Concerning Sources of Potable Water for St. Thomas, V.I.

PURPOSE OF STATEMENT

Section 3 of Public Law 85–913, approved September 2, 1958, authorizes the construction, operation, and maintenance by the Virgin Islands Corporation of salt water distillation facilities in St. Thomas, V.I., subject to the condition that the Secretary of the Interior concludes "that such facilities will most economically and expeditiously provide an adequate supplemental supply of potable water for St. Thomas." The section further requires the submission to the Interior Committees of both Houses of the Congress of an explanatory statement of such conclusion of the Secretary, "together with the reasons therefor and supplemental data concerning alternative sources of water which have been investigated."

On the basis of all of the information currently available, and for the reasons described below, the Secretary has concluded that salt water conversion facilities will most economically and expeditiously provide an adequate supplemental supply of potable water for St. Thomas. It must be recognized, however, that there are several methods of salt water conversion, each of which necessarily involves different engineering and cost factors, and a determination as to the particular method to be utilized in St. Thomas cannot be made in advance of further study. Further study is in progress, under an architect-engineer contract between the Virgin Islands Corporation and the Bechtel Corp. When the results of that study are known, the Secretary will communicate further with the committees and advise them as to the method of conversion selected. At such time, the "principal construction contract" will be submitted to the committees as well.

BACKGROUND

The need for additional potable water for the island of St. Thomas in the Virgin Islands is well established. Numerous studies of sources and quantities of the additional water required have been made. Two of the latest studies, both by consulting engineers, are those prepared by Gibbs & Hill in association with Mr. Sheppard T. Powell, and Tippetts-Abbett-McCarthy-Stratton. Each has concluded independently that sea water conversion is the practical solution to the water shortage problem. The conclusion is supported by the independent study of Mr. Goodrich W. Lineweaver, of the staff of the Senate Interior Committee, as a result of his careful examination of the problem in 1956.

Additional reports and studies pertinent to this problem have been reviewed. These reports, including those cited above, consist of the following:

1. Gibbs & Hill, Inc. and Sheppard T. Powell, "Potable Water Supply for Charlotte Amalie, St. Thomas, V.I.," May 9, 1956.
2. Tippetts-Abbett-McCarthy-Stratton, "Potable Water Supply for St. Thomas, V.I.," November 20, 1958.
3. Goodrich W. Lineweaver, "Potable Water Problem, St. Thomas, V.I.," committee print, Committee on Interior and Insular Affairs, U.S. Senate, January 15, 1957.
4. R. L. von Trebra, Director, Caribbean area, Soil Conservation Service, "Preliminary Report—Domestic Water Supply for Charlotte Amalie, St. Thomas, V.I.," memorandum of February 14, 1957.
5. Thomas W. Vaughan, geologist, U.S. Geological Survey, "Ground Water Resources of the West Indian Islands, St. John, St. Thomas, Culebra, and Vieques, and of the Eastern End of Puerto Rico," 1919.
6. Charles L. McGuinness, geologist, U.S. Geological Survey, "Ground Water Reconnaissance of St. John, V.I.," 1946.
7. Harrison P. Eddy, Jr., "Water Supply, Charlotte Amalie, St. Thomas, V.I.," October 3, 1951, and letter dated October 8, 1951.

There are several methods of converting sea water to potable water. As indicated above, the particular sea water conversion process for the St. Thomas facility has not been selected, because economics of the various commercial processes available must be studied and evaluated prior to making the process selection.

To supplement present supplies in St. Thomas, it is considered necessary to provide with the least possible delay a dependable source of at least 250,000 gallons of potable water per day. This must be followed about 5 years later by provision for an additional 250,000 gallons per day with still another 250,000 gallons per day additional by 1975.

The U.S. Congress, realizing the critical problem of potable water shortage on the island of St. Thomas in the Virgin Islands, has provided for the construction of facilities to alleviate this situation.

ALTERNATIVE SOURCES

Alternative major sources of potable water which have been studied in reaching the conclusion include:

- (*a*) Barge supply.
- (*b*) Pipeline from Puerto Rico.
- (*c*) Ground water.
- (*d*) Watershed areas.
- (*e*) Paved catchment areas.
- (*f*) Sea water conversion.

(*a*) *Barge supply*

The importation by barge of potable water has been used to augment the St. Thomas supply for for some years when required. The quantity has ranged in those years, depending on rainfall, from a few million to many millions of gallons.

The Department of the Navy has lent the utmost cooperation in this operation, depending upon the availability of its facilities for the purpose. On occasion it has made no charge for this haulage and on other occasions its charge has ranged between a nominal charge to the commercial rate of $16.84 per thousand gallons.

In addition, the Government has done this hauling by Government-owned barge with costs of operation of $5.64 per thousand gallons; and it has also resorted to haulage by commercial barges at charges ranging from $7.52 to $15.24 per thousand gallons, depending in part on the source of supply which, for the most part, has been Puerto Rico.

There was imported by these various methods in the fiscal year 1958, a total of 39,104,400 gallons at an average cost of nearly $5 per thousand gallons. All of these cost figures embrace only the delivery of the water to the intake facilities of the system and include no part of the cost of distribution.

These costs of barging water are considered excessive as compared to other methods of providing potable water. In addition, the dependability of the barging operation is questionable especially in this tropical area where storms interrupt regularly scheduled trips. The barge owned by the Virgin Islands Government for the purpose of such haulage from Puerto Rico sprung a leak and sank on June 23, 1959.

Because of the hazards, the lack of dependability, and the high cost involved, the barging of potable water is not recommended.

(*b*) *Pipeline from Puerto Rico*

With reference to a submarine pipeline supply from Puerto Rico, the Tippetts' report estimates a single submarine line approximately 253,000 feet long, of which 204,000 feet would lie under water at depths varying between 40 and 120 feet, with necessary pumping stations and storage tanks, would cost approximately $7 million, and the cost of the delivered pumped water would be over $11 per 1,000 gallons to supply the 1960 St. Thomas demand. As the potable water demand increased, this cost would be reduced, but the average cost would remain high in comparison with supplies from other sources. In addition this single submarine line could not be considered a satisfactory, dependable means of supply, as a single break in the underwater section of the line would be extremely difficult to locate and repair speedily. Accordingly, this source is not recommended.

(*c*) *Ground water*

Quantities of ground water available are extremely limited according to all evidence to date. Geological reports confirm that water cannot be produced in adequate volume from wells. Further, the water from the numerous existing shallow wells is too saline for human consumption and would require treatment.

Geologist T. W. Vaughan in 1919 reported that "water from artesian sources in any appreciable quantity in the Virgin Islands * * * is physically impossible. * * *"

Geologist Charles L. McGuinness in 1946 reported that on St. Thomas the rocks exposed at the surface are quite highly weathered, contain little quartz, and tend to weather chemically to clay rather than to disintegrate into gravels rich in quartz. Below the zone of weathering, the rocks are relatively dense and impervious and the joints, though numerous, are narrow. Wells obtaining their water supply from the bedrock may be expected to have only small yields.

Because of the limited quantities and poor quality of well water, this source is not recommended.

(*d*) *Watershed areas*

The only watershed on St. Thomas adaptable to development for adequate water storage and supply is that of Turpentine Run near the eastern end of the island. A suitable damsite is available for the construction of a concrete dam needed to impound water. The yield from rainfall on this watershed, however, is not enough to provide the additional water needs on the island. In a letter dated April 30, 1957, the Director of the Geological Survey stated, "The water supply available from the Turpentine Run Valley on a perennial basis might be as much as 50,000 gallons per day, and conceivably in wet years it might be as much as 100,000 gallons per day. It therefore would serve as a supplementary rather than a principal water supply if it were used for Charlotte Amalie." The reason for this is that the anticipated supplies represent only 20 to 40 percent of estimated immediate additional needs.

Data obtained since 1957 indicate that as much as 50,000 gallons per day of potable water might be obtained from Turpentine Run, but this quantity would fail to satisfy the present and foreseeable future needs of Charlotte Amalie.

The Tippetts' report has considered construction of a dam on Turpentine Run. They estimate that the cost of constructing the dam and providing related facilities would be approximately $2,550,000. Annual fixed charges for this investment plus operating costs are estimated to be $146,000 to deliver 21.9 million gallons of potable water per year. This results in a cost of $6.65 per thousand gallons delivered to the distribution system.

The report by von Trebra of the Soil Conservation Service, referred to above, states in part: "Runoff studies made by the Navy at this site, and yield estimates from available studies in Puerto Rico both indicate a sustained yield of about 1.7 feet or a fairly dependable annual storage of 210 acre-feet. However, annual loss by evaporation on a reservoir this size might be as much as 48 inches from a pond surface of 200 acre-feet of loss from a 50-acre lake surface. This would mean there could be very little carried over into a very dry year and so no assurance of a dependable supply would exist in this plan alone."

Because of the relatively low yield and high cost of water from Turpentine watershed, this source is not recommended.

(*e*) *Paved catchment areas*

The rainfall runoff from paved catchment areas constitutes the principal source of potable water produced at present on St. Thomas for distribution within the urban area of Charlotte Amalie. Additional catchment areas and storage capacity can be built to provide a dependable supply of additional water required. The cost of providing catchment areas and storage have been estimated and presented in the engineering reports previously referenced. These costs are summarized for comparison as follows:

Plant item	Tippetts (1958)	Gibbs (1956)
Gallons per day planned	220,000	200,000
Land required, acres	120	150
Land required, cost	$72,000	$33,300
Clearing land	27,000	16,650
Excavation	910,000	222,000
Concrete paving	3,180,000	1,755,650
Concrete curbs and fencing	169,000	251,600
Raw water storage (23 million gallons)	1,000,000	[1] 4,440,000
Piping and valves	44,000	118,400
Filter plant and clear well	245,000	740,000
Contingencies and engineering	1,400,000	1,924,000
Total cost	7,047,000	9,501,600

[1] 47 million gallons.

The annual costs of producing the additional water are summarized for comparison as follows:

Cost item	Tippetts	Gibbs
Capital expenditure	$7,047,000.00	$9,501,600.00
Financial charge	363,000.00	475,000.00
Maintenance and operation	19,000.00	12,000.00
Filter plant and pumping	31,000.00	8,000.00
Total	413,000.00	495,000.00
Per 1,000 gallons (365 days operations)	5.15	6.78

Eddy in 1951 estimated that an additional potable water supply of 91,000 gallons per day from 39 acres of additional paved catchments, storage facilities, and filters, including engineering and contingencies, would cost $3,900,000.

The foregoing cost estimates indicate that these capital and annual costs will be appreciably greater than for an equivalent salt water desalinization plant. In addition, the additional catchment areas on the hillsides around Charlotte Amalie would present an unattractive appearance and could easily constitute a deterrent to tourism. This in turn would tend to depress the island's economy, which is heavily dependent upon tourism. For these and other reasons the construction of new paved catchment areas for the additional source of water supply is not recommended.

(*f*) *Sea water conversion*

Costs of producing the required additional potable water by sea water conversion have been estimated by the consulting engineers previously referred to. These costs are presented in their reports and are summarized as follows:

Item	Tippetts	Gibbs
Gallons per day	250,000	200,000
Total installed cost	$1,725,000	$1,550,000
Production costs per 1,000 gallons	$3.52	$4.28

Subsequent research and studies by the Office of Saline Water indicate that methods of converting sea water are being developed which would considerably reduce the estimated production costs. The plant proposed for St. Thomas will be operated in conjunction with the power facilities and therefore both the salt water distillation plant and the steam turbine electric generating facilities will make joint use of the steam to produce potable water and electricity. The applicable cost thereof will be allocated between the two projects. For this reason, it is anticipated that potable water will be produced at a cost not to exceed $1.75 per thousand gallons.

The reports of both consulting engineering firms recommended the sea water conversion process as the most practical and economical method for producing the additional potable water required for St. Thomas.

CONCLUSION

From a study of the various alternative sources of additional potable water for St. Thomas and on the basis of information now available, the Secretary of the Interior has concluded that, of the facilities studied, a sea water conversion plant will most economically and expeditiously provide the additional potable water needed by the people of St. Thomas. The Secretary further concludes that such plant will be the most reliable source of the supplemental supply which is needed.

A decision as to the method to be used in converting sea water to potable water will be made as the result of an economic study currently underway, and a statement concerning such decision will be communicated to the committees as soon as possible.

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